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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 5.00	Members	$ 5.00
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Associates	10.00	Associates	10.00
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This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.

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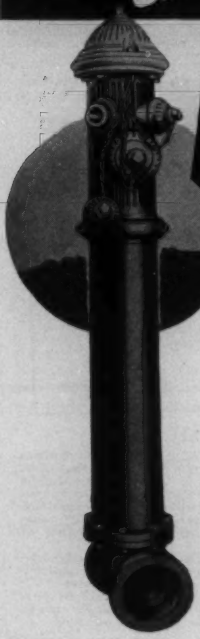

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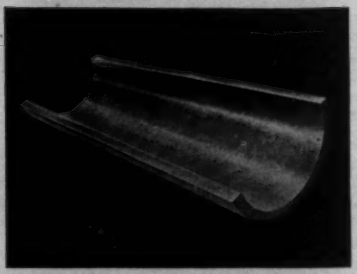

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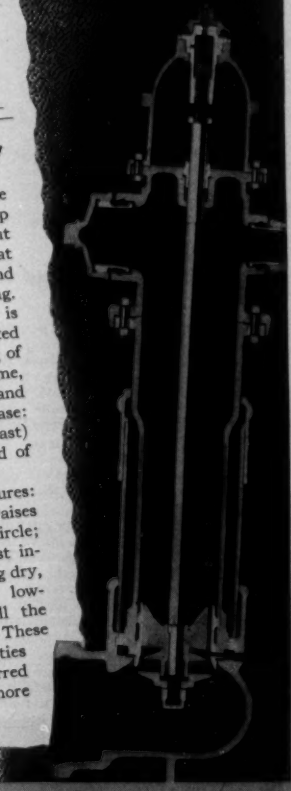

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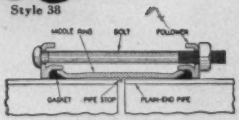

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Dresser Couplings are simply installed . . . and easily salvaged for new lines. Two resilient gaskets held in compression, grip pipe tightly . . . but also permit considerable latitude in pipe deflection to permit building curved pipelines. This flexibility also permits expansion and contraction of pipe sections without setting up harmful stresses . . . the key to the decades of service with practically no maintenance so characteristic of Dresser-coupled pipelines.

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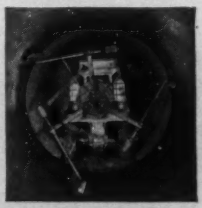

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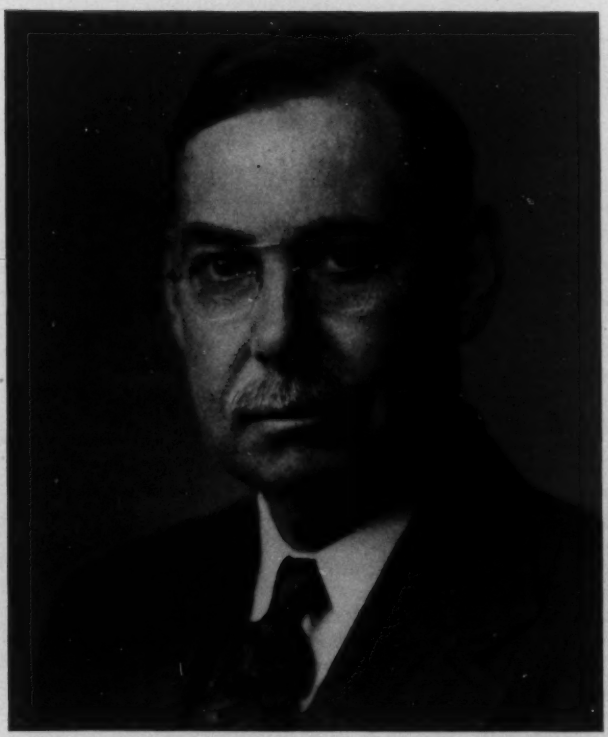

John Haley

HAROLD W. GRISWOLD

President of the New England Water Works Association 1945-46

New England Water Works Association
ORGANIZED 1882

VOL. LX MARCH, 1946 No. 1

This Association, as a body, is not responsible for the statements or opinions of any of its members

THE FINANCING OF WATER-MAIN PIPE EXTENSIONS

BY WALTER C. CONROY*

[*Read at Superintendents' Round Table, Feb. 15, 1945.*]

THE topic chosen for discussion at the Superintendents' Round Table today is, as you know, the financing of water-main pipe extensions. It is no doubt well to discuss this topic at this time, as it bears an important relation to post-war planning, particularly in those communities which still have a great deal of undeveloped land and which are likely to experience a considerable building boom soon after the war is ended.

Belmont is one of the communities situated close to Boston which not only experienced a very considerable building boom following the previous world war but had experienced very considerable growing pains prior to that war. At the present time there is land available in Belmont upon which it has been estimated 1,500 homes may be built. A large portion of this land is entirely undeveloped. We in Belmont therefore anticipate having another extensive building boom after the present war ends.

The writer assumes he has been asked to speak on this subject chiefly for two reasons: namely, the rather wide experience we have had in the past 35 years in financing main pipe extensions, and to describe the regulations governing such extensions which, with some few clarifying amendments, have been in effect and have worked to good advantage since they were adopted at the close of 1926.

Incidentally, the writer has personally had seventeen years' experience in such matters, for eight years as a member of the water board and for nine years thereafter in connection with the active management of the water department, first as office manager and then for the past four years as general superintendent. Mention of this is made because such experience embraces roughly half of the period during which Belmont experienced its exceptionally rapid

*General Superintendent, Water Department, Belmont, Mass.

development from a small town to a community which is larger in population than twelve cities within our Commonwealth.

A few facts will suffice to indicate to you Belmont's phenomenal growth, going back as far as 1909:

Year	Population	Miles of main pipe	Number of services	Average daily consumption (gal)	Revenue 1909-1926
1909	5,305	23.07	888	310,100	
1926	16,400	47.9	3,463	1,056,900	$ 643,557.11
Increase (%)	209.1	107.4	290.0	240.8	
					1926-1944
1944	28,600	76.21	5,669	1,632,100	$2,180,804.53
Increase (%)	74.4	59.1	63.7	54.4	238.9

You can readily perceive from the above facts that, when "growing pains" is used in connection with the expansion of Belmont in the past 36 years, it is a rather apt term in connection therewith. So much has been stated preliminary to getting down to the meat of the subject for discussion.

Until 1927 Belmont carried on its main pipe extensions under the guaranty form of arrangement, by reason of which the real estate developer was required to guarantee to the town a gross income of not less than 6% per annum from the extension made for him, the agreement stating that the developer guaranteed to pay 6% interest annually on the actual cost of laying and constructing the extension, but that the developer shall not be bound to pay in any year any further sum than the difference between the said 6% and the aggregate of the gross yearly water rates collected from the consumers of water supplied through the extension.

From 1909 to 1926 inclusive, for construction purposes, Belmont had floated $230,000 in bond issues, applied from surplus water revenue $134,000, and collected for construction work $71,000—a total of $435,000—and had expended close to the latter amount for new construction in that same period. Approximately 21% of the water revenue collected in those years was used to finance construction. At the close of 1926 our bonded debt was $186,500 on a plant valua-

tion of $470,000, the bonded indebtedness being therefore nearly 40% of the investment.

In the annual report of the board of water commissioners for 1926 the following comments appear:

"It has been the custom for more than twenty years to make extensions of main pipes upon obtaining written guaranties of income amounting to 6% of the cost of the work. This was no more than sufficient to reimburse the town for interest and the cost of the water supplied, without considering the repayment of bonds, or the cost of operation. The demands for extensions have necessitated borrowing considerable sums for several years past, and the requirements for interest and serial payments of bonds have become so burdensome that an increase in water rates would soon become necessary unless some method of limiting the borrowing were adopted."

The commissioners no doubt at this time visualized that the water system would require considerable reinforcement in the years to follow, and such a program was inaugurated in 1934 and 1935, requiring bond issues aggregating $135,000. Therefore, December 31, 1926, the commissioners adopted the regulations which since have been in effect, with certain changes which will be mentioned later. These regulations provided as follows:

In the case of extensions for supplying water to one or more individual applicants, such applicants were required to guarantee annual payments for water amounting to at least 10% of the cost of the extension for a period of ten years. "In computing the amounts due under such guaranty, all sums received in each year as water rates from water takers upon the extension shall be credited, but no such credits shall operate to reduce the amount due from the guarantors below the amounts at regular water rates." This part of the regulation applied to extensions in existing town ways.

"In cases of subdivision of lands for development, the promoters shall be required to pay the town a sum equivalent to three-fourths of the estimated cost of laying the main pipes in the new streets, if all such pipes were six inches in diameter, the town assuming the additional cost of such larger pipes as the water commissioners may deem necessary. Such payment must be made before the work of construction is undertaken." This part of the regulation related to extensions in private land.

In 1931 the following paragraph was added to the regulations:

"In real estate developments the water main pipes must be provided in all streets and must be extended to the limits of the development, including connections in boundary streets if such exist. Owners of such developments will not be permitted to limit the main pipes to such amounts as will allow domestic supplies to all lots, but must accept the decision of the town as to the size and amount of main pipe necessary to properly serve the development, including fire protection service, and to allow reasonable facilities for extensions in the development of adjoining lands."

At this point it might be well to state the authority of the board of water commissioners in this connection, which is expressed in the town by-laws as follows:

"The commissioners may grant an application for an extension of the water pipes upon such terms as they deem for the best interests of the town. . . ."

On May 3, 1937, the regulations affecting the extensions of water-main pipes in private and public ways were revised and adopted in changed form and have prevailed in such form since then. As revised, the regulations eliminated mention of the old form of guaranty arrangement and placed all extensions on one and the same basis, requiring applicants for such extensions to pay three-fourths of the cost of the work involved. The revised regulations increased from 6 to 8 in. the size of the main pipe the applicant would be required to pay his proportion of the cost of constructing.

The regulations provide for the applicant filing an application in prescribed form, accompanied by a plan of the proposed development, for the approval of the board of water commissioners. Upon approval of the application for the extension by the board of water commissioners, an estimate of the cost of the work is prepared and furnished to the developer, showing the entire cost thereof, excluding hydrants and their connections, and showing the amount of the deposit required of the developer, namely, three-fourths of the cost of the work. Incidentally, in figuring the cost of the work, an item of 15% overhead expense is included.

The regulations provide that the town may consent to the developer's arranging to have the excavating and backfilling of the trenches, except a certain amount of the covering of the pipe, performed by labor of his own hiring, in which event an arbitrary price of not greater

than $.30 per lineal foot of trench is allowed the developer in determining his share of the cost of the extension, which allowance, subject to the discretion of the board of water commissioners, may be taken into consideration in determining the amount of the deposit required of the developer or may be left for later consideration when the final cost of the work has been determined.

Upon receipt of the deposit required of the developer it is forwarded to the Town Treasurer, who sets it up in a special deposit account. Upon completion of the work, a final accounting of the expense thereof is made and the three-fourths cost to be borne by the developer is determined, minus any credit due him if the work of excavating and backfilling was provided for by him. A bill is then made out to the developer and forwarded to the town treasurer, with the request that he apply the necessary amount of the deposit on hand to the credit of the bill and refund to the developer the amount on deposit in excess of the bill.

This arrangement has worked out very satisfactorily. Since 1926 approximately $91,000 has been collected from real estate developers towards the cost of financing main pipe extensions, which, together with interest, represents a saving of approximately $110,000 to the water takers of Belmont.

Another point it might be well to mention here for your enlightenment is that, in years when we have had good reason to anticipate receiving certain sums of money in the form of main pipe payments, we have had the estimated total amount of such anticipated receipts included in our construction appropriation for the current year, which duly appropriated sum thereby becomes available for our use in such current year, if, as and when received, in whole or in part. This procedure has been very helpful in ordering our finances.

Some protests concerning the regulations have arisen now and then, in all of which cases the board of water commissioners maintained a firm stand, resulting in the developer's having to conform to the regulations.

The prime mover in the adoption of these regulations was a former president of the New England Water Works Association, Charles W. Sherman, who is well known to many of you here and who served for 24 years as a member of the Belmont Board of Water

Commissioners. I mention Mr. Sherman here, because I believe he deserves a lot of credit for his vision in the matter and for the success which has come of the arrangement.

Bond issues to the extent of $255,000 have been necessary since 1926 and considerable financing during that time has been done from surplus revenue—that is, the excess of water rates and miscellaneous revenue over estimated receipts—depending on the fluctuation of income from year to year. However, thanks in large measure to the successful operation of the regulations affecting main pipe extensions, our bonded indebtedness as of January 1, 1945, is only $62,000, or roughly 7% of our investment, compared to a bonded debt of about 40% of investment at the close of 1926.

Comparative information in relation to construction funds, source of the same, expenditures, relation of source of funds to main pipe expenditures, revenue from water rates and surplus of latter appropriated for construction purposes, for the two eighteen-year periods, 1909 to 1926 and 1927 to 1944, is given in Appendix A. This shows that, since the adoption at the close of 1926 of the regulations governing main pipe extensions, the volume of bond issues necessary decreased proportionately 12.0%; receipts for main pipe construction increased proportionately 12.5%, and financing from surplus revenue decreased 3.2% proportionately, compared with the preceding 18-year period.

The relation of the source of construction funds to main pipe expenditures alone for the two eighteen-year periods is as follows:

	1909-1926	1927-1944	Proportionate change
Bond Issues	73.1%	58.8%	14.3% decrease
Main Pipe Receipts	3.0%	21.1%	18.1% increase
Surplus Water Revenue	23.9%	20.1%	3.8% decrease

Water-rates revenue appropriated for construction purposes compared as follows:

1909-1926	1927-1944	Proportionate change
20.8%	7.9%	12.9% decrease

Appendix B shows even more plainly the effect of the adoption of these regulations. It shows that from 1909 to 1926 operating and other expenses amounted to 77.4% of the water-rates portion of

operating income, compared to 93.4% for the years 1927 to 1944—a variation of 16.0%. Bond retirement from 1927 to 1944 amounted to $362,500, representing 17.8% of expenses, while in 1909 to 1926 the amount retired was $57,000.00, representing 11.4% of expenses. For the period 1927 to 1944 the cost of water represented 50.1% of expenses, compared to 46.0% of expenses for the years 1909 to 1926. For the period 1927 to 1944 the cost of maintenance and operation was 26.8% of expenses, compared to 30.5% for the years 1909 to 1926.

For the period 1927 to 1944 interest on bonds was 5.3% of expenses, compared to 9.8% for the years 1909 to 1926. This reversal of trend was due to the much lower rates of interest which prevailed on bond issues from 1934 to 1941, ranging from ¾ to 3%.

For the period 1927 to 1944, compared to the period 1909 to 1926, operating and other expenses had increased 309.2%, while the revenue from water rates had increased only 238.9%.

It becomes obvious from the facts and figures shown in appendices A and B that, but for the timely adoption in 1926 of a new policy in connection with the financing of main pipe extensions, an objectionable increase in the water rates would have become necessary to solve the financial problems created by the enormous expansion of the town in the preceding 18 years and the outlook for its continued rapid growth in the period that was to follow. The fact that the present method of financing main pipe extensions has been in effect for the 18-year period, 1927 to 1944, explains the use of the preceding 18-year period for comparative purposes. At the present time we have accumulated for construction purposes the sum of $60,600, which will probably save us the necessity of floating any additional bond issues in the next few years at least.

We understand that we have the only case on record—or at least that was so a few years ago—of court action which finally reached the Supreme Judicial Court of Massachusetts, and which was decided in our favor, on the old form of guaranty arrangement in connection with the financing of main pipe extensions. The agreement was in connection with a main pipe extension of 2,451 ft of 8-inch main pipe at a cost of $6,811.62, from which was deducted $1,025.50, the estimated cost of constructing a 6-inch main pipe in the location, leaving

$5,786.12 as the principal sum upon which to base the amount of the annual guaranty required, spread over a period of ten years. A credit for water rates collected annually in connection with such extension was provided for, which was to remain in effect during the ten-year period, unless in any year of such period the revenue from the extension equalled or exceeded the 10% guaranty.

This agreement was consummated August 19, 1929, and the principal to the agreement adhered to it until August 7, 1931. One short extension had later been made to the original extension, for the benefit of another party under a similar agreement, about which no question arose. However, in 1932, in the interest of alleviating unemployment, we decided to extend the main pipe through the entire street as a town project and in that year laid 2,133 ft of 8-inch pipe in the street. The principal to the original extension had been in default at that time on his annual guaranty since the date previously mentioned—namely, August 7, 1931. Efforts had been made without success to collect from him the amounts due the town. After we completed the extension of the main pipe throughout the street, the principal contended that this action on our part nullified the agreement he had entered into and he assumed the position that he would make no further payments under the terms of the agreement. Consequently, in August, 1933, we instructed the town counsel to bring suit in the matter, which was instituted shortly thereafter and was followed by a further suit in 1937, to bring the amount in arrears up to date. The prosecution of the case had been delayed, due to the crowded condition of the court docket.

The principal had engaged counsel, who proceeded to contend that his client was entitled to credit for the revenue on the extension made by the town and even went so far as to make claim that he was entitled to credit for revenue from the existing main, to which the town connected its extension at the end of the street.

The case finally came to trial in 1937, being heard before a master. The writer appeared for the town. About three half days were required to hear testimony on both sides.

The clauses of the agreement involved read as follows:

"First, the Principal shall pay the Town of Belmont upon request at the end of each and every billing period for the ten years following the year of the com-

pletion of the water main to be constructed in pursuance of the Principal's application during which the revenue derived by the Town of Belmont from services connected with said water shall not have equalled or exceeded ten per cent, of the principal sum as hereinafter defined, the amount of the deficiency for every such period in any one year combined, or

"Second, if the annual revenue from services connected with said main shall in any one year exceed ten per cent, of the principal sum as hereinafter defined and the Board shall by resolution duly passed at any regular meeting vote to cancel this bond for the reason expressed in such resolution, that in the opinion of said Board the aggregate annual revenue from services connected with said main will thereafter exceed ten per cent, of the principal sum as hereinafter defined; then this obligation shall become void, otherwise to remain in full force and effect. By the aforementioned principal sum is meant the actual cost of constructing the main water pipe above referred to, provided, that if a main water pipe larger in diameter than six inches shall be constructed, then from said actual cost shall be deducted such part of said cost as said Board shall attribute to the excess in diameter over and above six inches. In determining said principal sum the decision of the Board shall be final and binding upon Principal and Surety."

We based our case entirely on the validity of the agreement entered into with the principal, which we contended was negotiated in good faith by the parties at interest and to which the principal was bound by his signature, and that of his wife as surety, to conform. The able special counsel employed by the board of water commissioners stressed to the court that the question of law involved hinged on the validity of the agreement and the understood reasons for its existence—namely, the development by the principal of the land, which the extension made under his application was designed to serve, and from the sale of which he had no doubt derived a profit.

The opposing counsel engaged an engineering expert in an effort to establish the alleged point that the wooded section bordering the street constituted a fire hazard, which would have made it necessary in any event to provide a main pipe in the street for fire-protection purposes. We denied that this was so. Just as an aside, the writer knew the opposing counsel as well as he knew the counsel representing the town. Once, while we were enjoying a short recess outside the hearing room, the opposing counsel said to me, "Off the record, Walter, didn't you extend that main on account of the fire hazard in the neighborhood?" The writer replied, "Joe, if you have any questions to ask me, ask them when we get back in the hearing room."

The main point of all stressed by the opposing counsel rested on the interpretation he endeavored to get across in connection with the word "services" appearing in the first and second clauses of the agreement. He quite confidently predicted he would win the case on this particular point, which he dwelt upon at considerable length, endeavoring to his utmost to break the writer down.

He contended that the word "services" as contained in the agreement implied that it covered services to any and all customers who were benefited by the extension made beyond the principal's extension (it being a fact that property had been developed and was being supplied with water from the later extension made by the town). He finally led up to the main point he sought to develop by the following line of reasoning, a strained interpretation in this case of the meaning of the word "services" as used in the agreement.

He put the questions below to the writer and the latter's answers were substantially as follows:

Q. "What do you next do after you have installed a water pipe to a consumer's premises?"
A. "Install a meter."
Q. "What do you next do after you have installed the meter?"
A. "Turn on the water."
Q. "What do you do the latter for?"
A. "To give service to the customer."

When I gave the latter answer, the expression which came over his face was one of great satisfaction, bordering on glee. However, the writer countered that the word "service" as it had just then been used was another meaning of the word.

Questioning by the counsel representing the town then developed the fact that in water-works parlance the word "service" also meant the service connection to a consumer's premises. That this was a true statement of fact was substantiated by testimony on the part of the writer as to the extent of his experience in the water-works field, including knowledge gained from visits to other water departments, and by the presentation of the annual reports of several water departments showing with unmistakable clarity that the word "services" was commonly used, and was understood by those connected with the water-works business when used in that respect, to mean service

connections to a consumer's premises. The auditor unhesitatingly acknowledged that it was clear to him that the word had the two meanings which have been mentioned. It then rested with him to determine his judgment of the meaning of the word "services" in the agreement, which in his findings he decided clearly meant service connections to property, and which under the terms of the agreement in question he found referred exclusively to service connections made to the main pipe extension covered by the agreement. The auditor, therefore, rendered it as his decision that the agreement was perfectly valid, that its application was limited to the main pipe extension it expressly referred to, which included only the services connected thereto, and that, therefore, the principal was duly bound to discharge the obligation he had thereby over his own signature incurred. The writer has not read the decision but understands that is the gist of it. The decision of the master was later affirmed by the superior court.

The opposing counsel then appealed the case to the Supreme Judicial Court, which upheld the decision of the superior court. Settlement was thereafter made.

We have two of these older forms of 10-year, 10% guaranty agreements in effect at the present time, which have a redeeming feature that did not prevail in earlier agreements of this nature—namely, a provision that, in determining the amount of the deficiency in water revenue to be paid by the principal to the agreement, there shall be deducted from the water revenue realized from the extension the cost of the water furnished by the Metropolitan District Commission, which cost we have determined as 60% of the water revenue.

In its broader aspects our present method of financing water-main pipe extensions, which requires real estate developers to bear in advance three-fourths of the cost of an 8-inch pipe, is a form of advance assessment, which, while it may be viewed as somewhat costly to the developer in the early stages of the development of his land, enables him to allocate the cost of the water distribution system in his development to the several lots of lands comprised therein. The shifting of this burden to the developer not only saves the municipality from incurring a larger bonded debt and the consequent obligation of meeting the interest thereon but has the desirable effect of stimulating the more rapid expansion of the real estate develop-

ment, carrying in its wake a corresponding uptrend in water revenue therefrom to offset the town's contribution to the cost of the extensions made.

The foregoing sets forth the experience of the Belmont Water Department in the matter of financing water-main pipe extensions, which recital of facts it is hoped may be helpful in the discussion of this subject here today. It is hoped that a full discussion will result and the writer will be pleased to answer any questions on the subject that he can.

In closing I would like to say that Belmont has been exceedingly fortunate in the high type of men it has elected to serve as water commissioners. The present membership of the board is typical of its predecessors in this respect. The present chairman of the board is Richard M. Cleveland, a well-known executive of the Worthington Pump & Machinery Corporation, with twenty-odd years' experience in the engineering field. Samuel Alcock, for many years a successful building contractor, has been a member of the board for twenty years. He collaborated with Mr. Sherman in the formulation of the policy adopted in 1926 concerning the financing of main pipe extensions. The third member of the board is Arthur G. Coffin, owner of a large automobile business located in Belmont. The town is most fortunate in the choice of such men to cope with its water works problems. The broad vision of these men, coupled with their background of business training and experience, is a decided asset to the people of Belmont.

APPENDIX A

Construction Finances of Belmont Water Department

	Jan. 1, 1909, to Dec. 31, 1926		Jan. 1, 1927, to Dec. 31, 1944	
	Amount	Per cent	Amount	Per cent
Source of Funds:				
Bond issues	$230,000.00	52.9	$255,000.00	40.9
Main pipe receipts	9,478.80	2.2	91,378.17	14.7
Service connection receipts	58,448.84	13.4	103,200.57	16.5
Miscellaneous receipts	2,982.18	0.7	1,797.57	0.3
Surplus water revenue	134,000.00	30.8	172,086.12*	27.6
Total	$434,909.82	100.0	$623,462.43	100.0
Expenditures:				
Main pipes	$314,775.29		$433,557.20	
Service connections	89,938.84		126,110.25	
Meters	26,424.45		28,453.46	
Miscellaneous	3,123.33		1,523.14	
Total	$434,261.91		$589,644.05	
Relation of Source of Funds to Main Pipe Expenditures:				
Bond issues		73.1		58.8
Main pipe receipts		3.0		21.1
Surplus water revenue		23.9		20.1
Water-Rates Revenue:				
Receipts	$643,557.11		$2,180,804.53	
Surplus appropriated for construction	134,000.00	20.8	172,086.12	7.9

*In the determination of this amount, miscellaneous receipts (cleaning service, etc.) of $23,099.56 and $4,913.95 received from the general tax levy in 1934 to offset Metropolitan assessment have been taken into account. Also $3,000.00 received from the general tax levy in 1941 for civilian defense.

APPENDIX B

EXPENSES OF BELMONT WATER DEPARTMENT FINANCED FROM OPERATING INCOME

	Jan. 1, 1909, to Dec. 31, 1926		Jan. 1, 1927, to Dec. 31, 1944	
	Amount	Per cent	Amount	Per cent
Operating Expenses:				
Water purchased for resale (Metropolitan water assessment)	$228,893.16	46.0	$1,021,044.77	50.1
Maintenance and operation	151,815.28	30.5	545,719.29	26.8
Bonded Indebtedness Expenses:				
Bond retirement	57,000.00	11.4	362,500.00	17.8
Interest on bonds	48,818.42	9.8	107,742.00	5.3
Allocated to sinking fund	11,285.00	2.3		
Total Expenses	$497,811.86	100.0	$2,037,006.06	100.0

Operating Income (Rates Portion Thereof Only):

	Amount	Per cent of income	Amount	Per cent of income
Income	$643,557.11		$2,180,804.53	
Expenses	497,811.86	77.4	2,037,006.06	93.4
Surplus	$145,745.25*		$ 143,798.47**	

*Some of this surplus was retained in maintenance account.

**This figure does not include miscellaneous receipts (cleaning services, etc.) of $23,099.56, $4,913.95 received from the general tax levy in 1934 to offset Metropolitan assessment, nor $3,000.00 received from the general tax levy in 1941 for civilian defense.

CHOOSING A PRIMARY DEVICE FOR FLOW MEASUREMENT

BY L. K. SPINK*

[*Read September 11, 1945.*]

THE water works engineer must have certain arbitrary standards on which to base recommendations on the choice of minor items of equipment. However, he owes it to his client to bring these standards up to date periodically.

While it is obvious that the development of a new and radical design of well, pump or controller would immediately change the picture regarding that particular piece of equipment, it is not as obvious that the development of new low-range differential instruments would affect the choice of the primary device. When a standard has been in existence for many years, sight may be lost of the basis upon which it was established and it becomes a prejudice.

The cost of metering equipment is usually a small item in the total cost of a pumping station and for that reason may not have been subject to the scrutiny given to major items of cost. Cost is a tangible consideration in the choice of a primary device or differential producer. Investment costs plus installation costs may be balanced against pumping costs with usual engineering precision. It is not sufficient to look at the initial cost and say that the Venturi tube costs more than the orifice and, therefore, the latter should be used; neither is it sufficient to look at the pressure-loss curves of the two and say that the Venturi will accomplish a power saving and, therefore, it should be used. Thousands of dollars have been wasted on the basis of such one-sided analysis.

If the cost of power is a serious consideration, it is only logical to select the lowest usable standard differential range in the commercial flow meter. Ranges as low as 2½ in. water are available, but a good 20-inch range may be obtained from almost any of the meter manufacturers. Because of pipe friction losses and because of possible

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future increase in load, velocities are usually kept low enough to measure accurately with this range. As a case representative of a small-town pumping station, take a flow range of 500 gpm through an eight-inch line. Using a 20-inch meter range (18.53 in. wet calibration), the d/D would be 0.56 for the Venturi and 0.68 for the orifice. The loss of the long-cone Venturi would be roughly 11% of 18.53 in. or 2.04 in. of water. The loss for the orifice would be roughly 53% of 18.53 in. = 9.85 in. of water. The head saved by use of the Venturi would be roughly 7.8 in. of water at full scale. At a normal operating rate of 64% of the differential scale, the saving would be 5 in. of water. The horsepower saving would be

$$\frac{400 \times 231 \times 62.4}{1728} \times \frac{5}{12 \times 33{,}000} = 0.0421 \text{ hp at } 100\%$$

pumping efficiency. Assuming 70% efficiency, the saving would be 0.045 kw. At a power rate of 1.5¢ per kwh, the saving operating 12 hours a day would be $0.045 \times 12 \times \$.015 = \$.0081$ per day or \$2.96 per 365-day year.

The price of an eight-inch long-cone Venturi tube is \$260; that of a Type 304 stainless orifice, \$19.65; difference, \$240.35. The time required to pay the extra investment cost alone thus figures 81 years. Add to that the time required to pay off the extra cost of installation, and it totals a long time to wait for your money.

Another example on a larger flow may serve to bring out the effect of pipe size on the cost balance. Take a pumping rate of 2000 gpm in a 16-inch pipe. With a chart range of 2500 gpm, the instrument would operate normally at 64% of the differential range. Using a 20-inch range (18.53 in. wet calibration), the orifice would figure roughly a 48% pressure loss, whereas the Venturi would figure 12%. The saving in head would be 4.3 in. at normal flow. The power saving would be

$$\frac{2000 \times 231 \times 62.4}{1728} \times \frac{4.3}{12 \times 33{,}000} = 0.181 \text{ hp}$$

at 100% pumping efficiency. At an operating efficiency of 70%, the power saving would be 0.193 kw. Assuming operation 20 hours per day for 365 days per year, the annual power saving would be 1409 kwh. At a power rate of 1.5¢ per kwh, the saving would be \$21.13

per year. The price of the Venturi would be $640, against an orifice cost of $72.50, or an investment difference of $567.50. The time required to pay out this cost from the power saving would be 26.9 years. Again, this time must be increased by the amount required to pay off the extra cost of installation.

Since the rate of pay-off increases more rapidly than the differential range, it is obvious that, with a 300-inch range, the picture would appear somewhat more favorable for the extra investment.

The cost of extra power involved in substituting an orifice plate for a long-cone Venturi may be figured for other operating data from the following formula:

$$\text{Cost of extra power per year} = \frac{Q^2 hm\ RFT}{E} \times \text{Cost-per-yr. factor}$$

Q = operating rate divided by flow scale of meter;
hm = differential range, inches of water (dry calibration);
R = power rate, cents per kwh;
F = operating rate of flow, gpm;
T = % of full-time operation;
E = overall efficiency of pumping unit in %.

For cost-per-year factor, see Fig. 1.

The intangible considerations are, of course, incapable of such precise analysis. For the present, no established engineering body has made a statement on the comparative accuracy of the two primary devices; therefore, the best that we can do is place them on a par for use on clean, non-viscous materials. A great deal of data gathered over the last 20 years tends to prove that, using published coefficients, measurement within 0.5% may be expected, using uncalibrated orifices constructed and installed in accordance with modern practice. The above figure excludes any error due to the recording, indicating or integrating apparatus.

The Venturi tube, it has been argued, offers more opportunity than the orifice to pass large objects without blocking. This may seem like a remote possibility in most pumping station discharges, although there have been cases in which foreign objects have been left in the pipe during fabrication or repair, and there may have been cases in which pump packing or other foreign material has worked into the discharge pipe during operation.

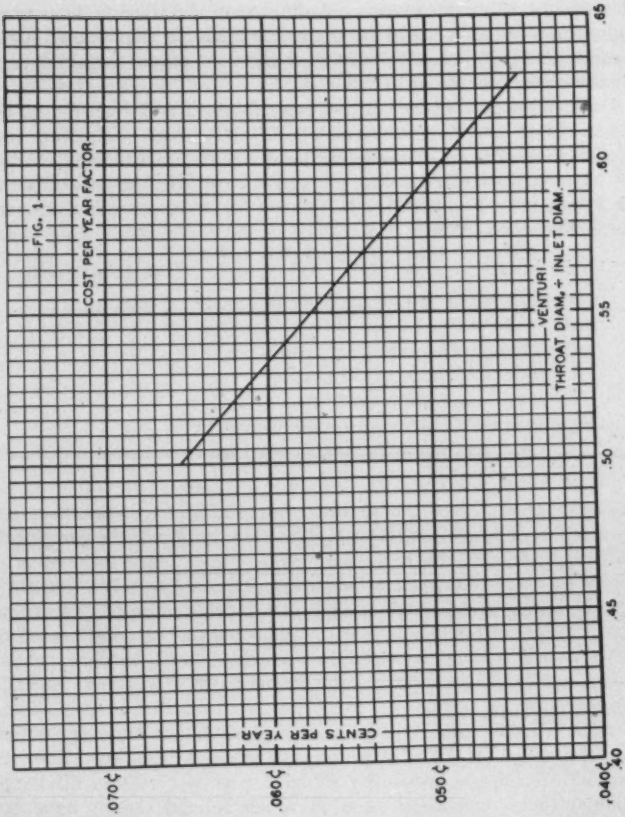
FIG. 1
COST PER YEAR FACTOR
CENTS PER YEAR
.070¢
.060¢
.050¢
.040¢
.40
.45
.50
.55
.60
.65
VENTURI
THROAT DIAM. ÷ INLET DIAM.

In defense of the orifice plate, it may be said that, for the same differential at the same rate of flow, its bore is larger and would permit a larger object to pass without blocking. It also creates a more or less dead space immediately upstream, where heavy material usually deposits. Sand or dirt deposited ahead of the orifice will usually decrease rather than increase its resistance to flow.

In contact with more than 50,000 orifice-meter installations on all kinds of service, we have experienced but a few isolated cases of orifices becoming plugged by foreign objects—most of them on natural-gas pipe lines immediately after fabrication. Rabbits which have crawled into pipes during construction and workmen's articles have accounted for most of the cases.

We also have on record a case in which a Venturi installation was blocked by a large disc of metal left in it during fabrication.

That the problem of flow stoppage is not serious is confirmed by the fact that the orifice is a standard primary device in the gas industry, where temporary flow stoppage would result in an explosion hazard in every home or installation supplied by the gas company.

Some of the advantages of the Venturi tube are of little importance on most water works jobs, but should be mentioned in case special conditions arise. It will handle a little more than 50% higher velocity than the orifice at the same differential. It will measure more accurately the flow of slurries, sewage or water containing considerable percentages of solids.

The orifice plate has the advantage of flexibility—that is, ease of replacement to fit altered flow conditions. It can be made by any first-class machinist familiar with the necessity of maintaining a sharp upstream edge. The complete process of manufacture and installation can be accomplished in a few hours in case of an emergency.

All in all, it would appear that, except on high velocities or dirty fluids, the intangible factors for and against the orifice and the Venturi just about balance out, leaving the matter of choice dependent upon a plain analysis of cost as illustrated by the example previously given.

The flow nozzle has the ability to handle the same high velocities as the Venturi tube. It also has some of its characteristics as to immunity to dirt and solids in suspension. In cost, it is between the orifice and the Venturi. Data on hand at the present time would

indicate that it is somewhat less accurate than the orifice, but a direct comparison with the Venturi is not available. When the throat is computed to give the same differential as an orifice, the pressure loss is about the same as that of the orifice, although for the same d/D ratio its pressure recovery is considerably higher. For velocities in excess of those which can be handled by the orifiee plate, and for dirty fluids, it is worthy of consideration.

The pitot tube gives a spot velocity measurement. As a flow measuring device, it is subject to all of the influences which affect the velocity distribution in the pipe. Velocity traverses may be made to establish the ratio of average velocity to that at some specific location but continued accuracy is dependent upon the maintenance of this ratio. The pitot tube is mainly useful for surveys, spot checks, determining flow ranges and rangeabilities and for rough measurements.

Each primary device has its own field of usefulness. Each has its advantages and disadvantages for any given measurement conditions. A correct selection can be obtained only by a careful balance of the characteristics against the requirements of the application.

EXPERIENCES OF A TRANSPORTATION OFFICER IN THE ETO

BY RICHARD KIMBALL*

[*Presented November 15, 1945.*]

My experiences and my views, as I express them here, are necessarily personal and not to be construed as remarks of an Army officer in an official capacity. I shall describe briefly the organizational setup of the Transportation Corps in the European Theater of Operations. Then I will tell a few of our most interesting experiences which will undoubtedly be of interest to you.

In the Zone of Operations of a Theater of War the Service Forces take up their function of supplying the Ground Forces. To accomplish that gigantic task, certain geographical areas are designated as Sections or Base Sections, usually commanded by a Brigadier General with a Transportation Officer on his staff. The Sections in turn are divided into geographical districts and on the district commander's staff you again find a Transportation Officer. Section sub-divisions stop here.

The Transportation Corps, however, breaks down further into sub-geographical areas, based in general upon important lines of communication—rail, road and water. Each area is under the supervision of a Railway Traffic Officer. A good many of you remember him in the last war, and all of you in World War II. He knows the precise location of all units in his area. The Transportation Corps needs this man to control and coordinate all movements. Since England is small and France not too large, in order to secure most efficient utilization of existing facilities certain restrictions had to be imposed. Through the Railway Traffic Officer we were able to regulate movement. For instance, to move twenty or more personnel by rail it was necessary to contact the Railway Traffic Officer. By the same token, to move five or more cars of supplies by rail, ten or more trucks by

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road, or any barges by water, all arrangements would be made with the Railway Traffic Officer. So much for our organizational setup.

Our first really interesting movement was known as "TORCH", the code name for the invasion of North Africa. We in the Transportation Corps probably had closer connection with that particular movement than any other branch of the service. Our personnel contacted local unit commanders, telling them that their outfit was alerted. This was the first time that we used our official directive from General Eisenhower, giving us the full authority of his Headquarters. We gave complete instructions as to the packing and marking of equipment and the scheduled move to port of supplies and personnel. Of course we were all guessing where the operation would take place but I doubt if more than five or six people in the European Theater of Operations knew, at that time, exactly where it was headed. A few guessed right; none really knew.

The "TORCH" operation was known as a "long sea voyage". In the transportation setup, all the way through, it had to be planning, planning, planning. Everything had to be coordinated to the *n*th degree. Rail facilities had to be set up so that we could follow movement through to a port and load a ship in a minimum of time, so that it could run outside and wait until the rest of the convoy was completed. We were advised that this particular operation would be of three to six weeks' duration. Supplies and vehicles moved to port approximately three to four weeks prior to the embarkation of personnel. That is rather interesting. Supply ships or slow-moving vessels would be loaded and dispatched to a rendezvous in the Atlantic Ocean, from which they would proceed slowly toward their destination. Then the speedier personnel ships, loaded two or three weeks later, would catch up with them at a designated place and all would go on to final destination as a complete convoy.

Our next very interesting operation, of which you have heard a great deal, was the invasion of Normandy.* This was of an entirely different type, for the initial phase in this completely tactical situation required that all craft and ships be combat-loaded. Movement to port had to be strictly regulated so that troops, vehicles and all supplies arrived simultaneously. For instance, an artillery unit could

*Code name, "OVERLORD".

not be dispatched to the far shore without its guns and ammunition.

A complex arrangement of camps was built on the southern coast of England. We used to say jokingly that the little island would sink if it weren't for the barrage balloons supporting it. Huge concentration areas were located thirty miles inland. A unit would be alerted for movement. This alert would probably give the commander two or three weeks' notice. He would requisition and procure final equipment, mark vehicles and accomplish the first stages of waterproofing. Then the unit would move into a concentration area where it would stay perhaps a week, after which it would move on to an assembly area about fifteen miles from the coast. You can picture the south of England, all along the shore, set up in this manner so that there were literally hundreds of assembly areas. In an assembly area the last stages of waterproofing were performed and the last packing and marking of combat-loaded vehicles were undertaken.

Enough personnel to load on one tide would move from the assembly area into one of four sub-areas, where they would remain no more than thirty-six hours. Of these four sub-areas one was embarking troops down to the loading point, one had troops that had been there for approximately twelve to twenty-four hours and another was being filled. The fourth was held as a spare to allow for a tide-loading return due to bad weather or tactical reverses. That was the only elasticity that existed to take care of an emergency.

As they left the assembly sub-areas all organizations were broken down into craft loads, so that there would be no more than a small proportion of any one unit within a craft. For example, a complete machine-gun platoon could not be placed in one craft. It had to be spread in working-unit proportions for combat efficiency. If one of those craft were knocked out, combat power would still be preserved. There was a continuous movement of convoys from sub-areas to regulating points, from which craft loads were called forward as loading facilities became available. Loading points were concrete blocks or wire-mesh surfaces laid over the sand, so that a landing craft could head up, load, get out into the stream, rendezvous for one complete tide convoy, pick up the naval escort and run across.

After the first month of invasion operation, we reverted to normal movement where troops and supplies could be sent separately to port.

Strict regulation was not necessary because, by that time, facilities on the far shore had been improved.

At first, ports, railroads and bridges on the other side were knocked out. Roads, as they existed, were about the only things that were fairly usable. Thus you can see why the Red Ball truck route originated, running from Cherbourg into Paris and on forward to the front.

Most of the truck companies were operated by colored personnel. I have an amusing recollection in regard to one of these truck operators. This particular soldier had a truckload of gasoline. He heard what one can do with gasoline in France. It was critical material and civilians would do anything to get it. This fellow drove down to Paris with his load and sold it for a suitcase full of thousand-franc notes. He next sold his truck and collected more notes. Then he decided he would purchase some sort of business in a location far removed from his headquarters. So he bought a house of ill repute and found business was pretty good. About three weeks after that he bought another one. Business was really booming. But he made one mistake. They picked him up when he appeared at a Post Exchange to buy cholocate bars to keep his madams happy.

The canal systems were very badly damaged; locks were blown up, barges sunk and obstructions left in the wake of enemy action. It took us many months to get them back in working order. Few people realize the capacity of the inland waterways of France. An average barge could haul between 250 and 350 tons, the equivalent of a full train-load. In eight days we could haul barges from Le Havre, Ghent or Antwerp into the canal system to Rheims. Thus, with these slow-moving carriers for non-critical items, we could relieve pressure on already congested rail lines. Repair of this important means of transportation therefore received a high priority. As a result, by June, 1945, the inland port of Rheims, 283 miles from the nearest ocean port, was handling 3,400 tons daily.

The next interesting experience was the Battle of the Bulge, December, 1944. Oise Section Headquarters was in Rheims. Bastogne was about 120 miles away. There was nothing between us and the expected Jerry breakthrough except the 101st and 82nd Airborne Divisions, about thirty miles away on either side.

We received an order to round up every truck we could get our hands on. Inside of twenty-four hours 600 trucks were available. They ranged from 2½-ton vehicles up to 10-ton tractor-trailers, high- and low-sided, some personnel and some cargo carriers. Our method of attaining the designated quota was not quite orthodox. We took 100 men and put them on every road leading into Rheims, the key transportation point in that operation. Any truck that came along, which did not belong to an Army combat unit or the Air Force, was "absorbed" for more useful immediate purposes. Thus the additional trucks were secured.

Eighteen hours after the trucks arrived, personnel of the 101st Airborne Division were "on the line". It was fast moving but we got them there. The weather was bitter cold and roads were icy. However, the operation worked out very well. Of the 600 trucks, I would say only 30 or 35 did not return within a reasonable period of time. A few were captured and some were utilized by the fighting airborne troops.

Oise, with headquarters at Rheims, was but one of five Army Sections in France. In order that you may have some idea of what was accomplished by the Transportation Corps in that Section, I would like to give you a few statistics.

	Nov., 1944, to V-E Day	V-E Day to V-J Day	Total
Supplies by Rail			
Tonnage Loaded	1,287,671	1,386,450	2,674,121
Tonnage Unloaded	2,209,586	2,012,888	4,222,474
Tonnage Re-consigned	562,626	553,960	1,116,586
Total Tonnage Handled	4,059,883	3,953,298	8,013,181
Tonnage Regulated through Section (in addition to tonnaged loaded, unloaded and re-consigned)	5,175,000	1,511,644	6,686,644
Personnel by Rail			
Troops	1,723,430	2,112,644	3,836,074
HATS (Hospital Trains)	104,359	37,005	141,364
Total	1,827,789	2,149,649	3,977,438
Road Movements			
Number of Convoys	4,013	4,252	8,265
Number of Vehicles	281,849	213,397	495,246
Number of Personnel	1,031,386	709,002	1,740,388
Barge Movements			
Tonnage Loaded	27,472	92,129	119,601
Tonnage Unloaded	80,057	277,137	357,194
Total	107,529	369,266	476,795
Motor Transport			
Tonnage Hauled	2,303,118	2,574,369	4,877,487

This gives you a fairly clear picture of the part the Transportation Corps played in World War II.

INTERNAL-COMBUSTION ENGINES IN WATERWORKS AND SEWAGE PLANTS

BY A. M. BOEHM*

[*Read November 15, 1945.*]

IN THE preparation of this paper, I had occasion to refer to a paper that was delivered before this same body way back on March 13, 1923, under the subject of "The Diesel Oil Engine for Waterworks Service."† At that time, the subject was so relatively new that it took four of our top engineers to do it justice. Messrs. Lucke, Hall, Chase and Spillmann were elected to do the job and they really did it in fine style. It was rather a question, at that time, of the "men carrying the subject" and I could not help contrasting that situation with the present, where the "subject is carrying the man." By this I mean, that the Diesel and gas engines have so gained in stature and general acceptance that today it is unnecessary to devote the greater part of the time allotted to justifying them by telling you how reliable or how efficient they are.

Rather, I should like to spend this time by showing you what has been done by others and what you and others may be doing in the immediate future with the latest developments in internal-combustion engines.

Developments in Stationary Diesel Engines. Design of stationary Diesels has held fairly true to form; *i.e.*, those features which have proved themselves in the field as desirable have been retained. The most important trend has been the general adoption of supercharging, mostly of the turbo-charger type, which has resulted in the following advantages:

1. Specific outputs increased from 40 to 50%, with substantial reduction in floor space, building size and foundations, over an equivalent unsupercharged engine.

2. A general lowering of the fuel consumption from full to half load, with the greatest gain made at light load points. As a

*Worthington Pump and Machinery Corp., 2 Park Ave., New York, N. Y.
†Lucke, Charles E., This Journal, 37:2, 145, June, 1923.

matter of fact, turbo-charged Diesels have a lower fuel consumption at half load than an unsupercharged engine has at full load.

3. The turbo-charger automatically adjusts itself to change in load, since its driving force is made up of the weight and temperature of the exhaust gases, which change with the load. Thus the engine cylinders are always supplied with the right amount of air for combustion, regardless of load.

With the adoption of turbo-charging, two changes in design were almost universally necessary:

1. Pistons had to be cooled to carry away the additional quantity of heat released, due to the ability to consume much more fuel. Piston cooling has taken the form, in most cases, of a spray of oil which is played back and forth against the under side of the piston crown by means of a nozzle in the eye of the connecting rod. The cooling oil used comes from the regular force-feed lubricating oil system of the engine running gear.

2. Inlet and exhaust valves, except in large engines, now seat directly in the head, instead of being carried in removable cages. This is done for two reasons:

a. To obtain better cooling by having the valve seat against a surface the other side of which is in direct contact with cooling water.

b. To provide the additional area necessary to handle the increased volumes of air and exhaust gas that are a natural function of turbo-charging, more air being required for both combustion and scavenging.

It has become more and more usual to encounter both oil-cooled pistons and valves seating directly in the heads, even in unsupercharged engines, since it has been found that these two changes permit of increased ratings and speeds. It is usual now to encounter 80 lb BMEP* and up to 1400 ft per min piston speeds in unsupercharged engines. Turbo-charged engines are usually found rated in a range from 112 to 120 lb BMEP, with about the same upper limit of piston speed mentioned above.

It goes without saying that lubricating-oil and jacket-water-cooling systems, exhaust silencers and air filters must be proportionally increased in size for the increase due to turbo-charging.

*BMEP = brake mean effective pressure.

Developments in Otto-Cycle Gas Engines. There is practically nothing to add to the long history of the developments in the low-compression spark-ignition gas engine as such. Designs have been refined, thus adding to appearance, reliability and safety but, basically speaking, not much has been done, nor is it likely that much can be done to improve its thermal efficiency. This type, however, is not obsolete and will continue in a narrower field to be the good, steady, day-in and day-out performer that it has always been.

Developments in the Dual-Fuel Engine. Manufacturers of internal-combustion engines, at one time or another, have always been faced with the problem of providing an engine that could operate on either oil or gas. There was a good reason for this, too, as localities or processes sometimes demand that gas be the favored fuel to be used as long or as much as it is available. Two examples of this will suffice to illustrate the point:

1. In certain sections of the country, natural gas is available at a lower price than fuel oil, if it is used during the off-peak season. This is generally for the seven months that constitute the warm-weather or non-heating season. During this time, the gas pipelines or gas companies have an excess of gas to sell and can afford to offer it at an attractive price. But during the cold-weather or heating months, the greatest demand is put on the gas facilities and they cannot afford to sell gas at an off-peak price during an on-peak season. In this case, an engine that could burn gas during the off-peak, attractive-price season and then conveniently change to fuel oil during the on-peak season, would be desirable.

2. Sewage disposal plants using sludge digestion and collection of gas find that when the plant first goes into operation it takes sometimes as long as three to six months before sufficient sludge gas becomes available for use in sludge-gas engines. In most cases it has been necessary to do one of three things:

a. Contract for electric service for this temporary condition at considerable investment for utility service and with high operating costs, compared with the operating cost later on, when gas is available at little or no cost.

b. Contract for gas service from the local utility to operate the

engine until sludge gas is available again, with high investment and operating charges.

c. Install a separate, Diesel-engine-driven generator unit to operate plant pumping or blower equipment until gas is available.

Here, an easily convertible engine that could be switched from oil to gas would be ideal.

Previous to August, 1944, in the United States the only conversion from oil to gas was obtained by changing a high-compression (450-475 lb per sq in.) Diesel oil engine to a low-compression (125 lb per sq in.) Otto-cycle spark-ignition gas engine. This lowering of compression fundamentally could be done in two ways:

1. By installing a water-cooled distance piece between the head and liner, keeping the same pistons and liners and taking about a 7% loss in power; *or*

2. Changing liners and pistons and gaining from 10 to 15% in power, due to the fact that larger diameter liners could be used, inasmuch as the maximum pressure in the low-compression gas engine was only about 360 lb per sq in. compared with about 600 lb per sq in. in the Diesel.

With both methods, a loss of about 25% in thermal efficiency was sustained, due to operating on entirely different thermodynamic cycles. Both methods required a substantial shut-down period to install conversion parts.

Previous to August, 1944, American engine designers had always thought that it was impossible to compress air-gas mixtures in spark-ignition Otto-cycle engines much above 125 lb per sq in., due to problems of pre-ignition. The mixture had the annoying habit of firing by auto-ignition on the compression stroke without waiting for the timed spark to ignite it. This resulted in loss in power and excessive peak pressures that were injurious to bearings.

Based on research and actual commercial results that had been obtained in England from 1937 to 1940, Worthington undertook the problem of perfecting an engine that would operate equally well on oil or gas, using Diesel high-compression pressures and no other ignition devices, except the heat of compression. In August, 1944, this was successfully accomplished with the following results:

a. Oil *or* gas could be used as fuel.

b. No shut-down was necessary to change from one fuel to another.

c. Load need not be relieved during time of fuel shifts.

d. Fuel consumption on gas at full load dropped 25% below the current Otto-cycle gas-engine consumption.

Truly remarkable results! But why was not pre-ignition encountered and how could the air-gas mixture be made to behave according to a pre-arranged schedule of ignition? The answers were relatively simple in theory but a great deal of ingenious research effort was required to make it a commercial proposition.

a. It was found that, if the air-gas ratio was made as perfect as customarily used in Otto-cycle engines, pre-ignition took place. But, if the mixture was made so lean that it was difficult to ignite, no pre-ignition took place.

b. To fire the lean charge, a small amount—5 to 7%—of fuel oil was sprayed into the air-gas charge on the compression stroke. The fuel oil readily ignited itself under the heat of compression and, in so doing, initiated, propagated and sustained the ignition of the air-gas charge. The fuel oil used for ignition is called pilot oil.

Once the principle was successfully demonstrated, improvements were rapid. In a short time Worthington presented a dual-fuel engine in the fullest sense of the word, one that could not only operate on *either* oil or gas, but on both these fuels simultaneously in any proportion of both from 100% oil to 95% gas and 5% pilot oil. Selection of fuels or proportions may be done manually by a mere partial turn of a hand-wheel in a matter of seconds, without interruption to the load or change in speed.

A later ultimate improvement was made by applying supercharging to the dual-fuel engine with all the advantages that were pointed out earlier in this paper. This was the first time that anyone, anywhere, supercharged a dual-fuel engine.

Briefly, these are the high spots of the developments in the stationary-engine field as it exists today.

INFECTIOUS HEPATITIS

BY ROY F. FEEMSTER, M.D.*

[*Presented December 20, 1945.*]

I DO not come before you posing as an expert on this particular disease, because there are very few experts on it. A Dr. Blumer down at New Haven has been interested in this disease for some twenty years and he has written a number of papers on it. Most of what I have to give you is information which I have acquired from reading the literature and from studies which have been carried on by one member of our department during the past year.

About a year ago, in two or three of our communities we had small outbreaks of this disease, which I will describe to you in a moment, and because of the interest, which has been increasing, we thought we would undertake to make some studies and find out what we could in our own state.

Infectious hepatitis is not a new disease, although one physician rather naïvely brought forward that statement in the Journal of the American Medical Association. He said, "This is a new disease which has come in with the second world war." That just is not so, because this disease has been known as long as we have had medical records. You will understand that, because it is a disease which is familiar to all of you. I am sure that you can look back and remember your friends or relatives who have had it in the past, because it is the old, familiar disease which is commonly known as yellow jaundice.

The most characteristic sign by which we recognize this disease is the fact that the skin and the eyeballs turn yellow some time during the illness, usually at the end of the illness. There are other symptoms and signs which precede this yellowness of the skin and eyeballs, and the symptoms vary somewhat, but the most prominent one is the fact that the person is below par, he does not feel well, he has certain distressing symptoms in the gastro-intestinal tract in the way of pains in various parts of the abdomen, sometimes nausea, feeling

*Director, Division of Communicable Diseases, Massachusetts Department of Public Health, 545 State House, Boston, Mass.

that he wants to vomit but never quite getting to it, but sometimes actually vomiting. There is usually a rise of temperature early in the disease. A person has fever, feels feverish, does not want to get on the job and do the day's work, and he sits around rather apathetically. The doctors might give a good many more symptoms, but that is enough for now, because you have probably seen individuals in just that state.

We must not think that every time a person's skin turns yellow or his eyeballs turn yellow he has infectious hepatitis. You see, infectious hepatitis is simply a term that designates a disease which is an inflammation of the liver and is caused by a germ of some kind which can be passed around. That is what the term means to the physician, and when he uses it that is the picture he has in his mind. Because jaundice is a symptom and may occur in a number of different diseases, the physician is not willing to have a particular disease called by that name, so that the medical men have concocted this new name, and that is why a good many of you thought it was a new disease.

There are other causes of yellow skin or jaundice. One of them is a disease known as Weil's disease, caused by a spirochete, while infectious hepatitis is caused by such a small organism that you can't see it through a miscroscope and it passes through the finest porcelain filter. We have recently had occasion to study cases of Weil's disease among the fish workers in Boston. Weil's disease is a more serious disease than hepatitis; it is fatal in a much larger percentage of the cases. Two of the individuals in this recent episode failed to survive.

Yellow skin can be caused by other kinds of infection of the liver. It can occur in other infectious diseases, such as typhoid fever and some of the other diseases with which you are familiar. It can also occur when a person has a cancer in the liver, blocking the bile passages so that the bile no longer gets down into the intestinal tract. It can occur as the result of gallstones, one of which gets loose and blocks the duct leading to the intestinal tract, so that the bile can't get out and it gets into the blood stream and finally into the skin. The only way for it to get out of the blood is in the urine, so that when a person has yellow jaundice, as we used to call it, in addition to having a yellow skin, the urine would be a different color, a bright

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yellow color. The color is noticeable particularly when you shake it up, as the foam on the top has a yellow stain. That is one of the simple tests by which a doctor can recognize this disease.

Why haven't we heard a great deal more about this disease, and why are we hearing a great deal about it now? One reason why we have not heard about it so much in the past, why we have not talked about it, is that it is quite a mild disease. Many of us have it and get over it within a few days with very little threat to life. We have a little discomfort, like having an intestinal disturbance, have a little uncomfortable time for a few days, and then get back to normal. It is a mild disease and, as might be expected, medical men and research workers spend their time on diseases which really cause more serious results and are a greater threat to life.

Here is a disease, therefore, which has been left on the shelf waiting for more interest in it. If that is so, why are we interested in the disease now? The principal reason is that just at the beginning of the war we had an episode which focused attention upon jaundice. This episode was associated with the fact that we can protect people against a very serious disease—yellow fever—which occurs in tropical areas, by giving them a vaccine made of the virus of yellow fever which is grown on the developing eggs of chicks and then is treated in certain ways. This vaccine deteriorates very rapidly, and it was necessary to have it in a very special kind of an environment to keep it from deteriorating. One of the best environments that was found to keep the vaccine good for a period of a few weeks was human serum. The Rockefeller Foundation, which was the principal manufacturer of this vaccine before the war, had gone to one of our medical schools and obtained blood from the medical students. One of those medical students happened to have the virus of infectious hepatitis in his blood at the time that it was taken, but nobody knew it because he was not yellow and there was not any characteristic symptom recorded in the immediate past which gave an idea that he did have this virus. That batch of serum taken from the blood of several students went into a pool that was used in several batches of yellow-fever vaccine, and a fair proportion of the individuals who received that particular vaccine developed jaundice. For some reason or other, either because of the way the vaccine was

handled or because there may have been a slightly different virus, it was a much more serious disease than infectious hepatitis. There was a great deal of liver destruction, so much destruction that some of the men who took the vaccine died. This incident occurred both in the military forces and in the civilian populations of South America and of Central America. Something like that, which occurs particularly among soldiers, is going to create interest, as you can readily understand.

As an interesting aside, one of the physicians from our department—Dr. Carroll—who had been in the Berkshire district and who had gone in as a reserve officer before the war and been assigned to Fort Knox, was one of the first individuals who noticed this association of taking yellow-fever vaccine and the development of jaundice.

Before we leave the vaccine, let me say that the process of manufacture was changed so that we would not have to have human serum to stabilize the virus. Since that has been done we have had no more jaundice among those who took the yellow-fever vaccine. That is another problem which has been solved. We have become more interested in infectious hepatitis because of this episode which occurred just at the beginning of the war.

Research in regard to infectious hepatitis is progressing rather slowly, due to the fact that up to the present time we have not found an experimental animal in which to carry on laboratory experiments. The animals which we usually use, such as mice, guinea pigs and rabbits, are not susceptible to the virus. Nothing happens to them when it is injected into them. Hence the only way in which we can carry on any experiments is to get some human volunteers, who are willing to contract this rather mild disease. Human volunteers have acted as guinea pigs and some of them have had some rather uncomfortable times. The progress will be slow as long as we have to use human beings as experimental animals. There are many questions which we would like to have answered, which will not be answered until we find better ways of carrying on the laboratory experiments.

Many viruses, including the yellow-fever virus, grow very readily upon the developing chick in the hen's egg, but so far this virus has not grown in that environment. Therefore we look to the time when we will have a better way of carrying on the laboratory studies. This

includes the development of a test by which we can determine whether a person is ill of this particular disease at a particular time, or has had it in the recent past. We have tests by which we can tell whether you have typhoid fever or not, or whether you have had typhoid fever recently, but we have not any such test for infectious hepatitis, so that we just have to use our eyes and say, "This person has a yellow skin," and we examine his urine and his blood. If we do not find the spirochete which causes Weil's disease, and if we do not find indications of cancer or gallstones, then we say it must be infectious hepatitis, but that is not very satisfactory. Another way would be to take some blood of an individual and use some human volunteers.

In addition to the recognized cases of persons who have the yellow skin, it is believed that some persons have enough resistance to the virus so that they may have a mild infection and yet not develop jaundice; in other words, there is not enough damage to the liver so that the bile appears in the blood and makes its appearance in the skin and the eyeballs. In addition to that, some individuals who have the disease may continue to carry the virus in the blood for a period of weeks after they have recovered from the disease. We have good reason to believe, therefore, that there are persons in our population at all times who are carrying the virus, who do not have the yellow skin at the time and may never have had a yellow skin. So that we have to think of these individuals as well as the ones that we recognize as being ill.

This virus is quite a hardy one. In the laboratory you can heat it to 56° Centigrade, which will kill a typhoid germ, and the virus will still cause the disease in human volunteers. This ability to survive is one of the necessary requirements for a disease which can be spread through the environment. It must be hardy, so that it cannot be killed readily by environmental conditions. On the other hand, we have other germs which die very rapidly when they get out into the environment. The germ causing meningitis dies very quickly, and the germs causing gonorrhea and syphilis die very quickly after they get out of the human body. Consequently most persons who acquire these diseases acquire them by rather close contact with another individual. A disease like typhoid fever, on the other hand, can be spread, because the typhoid germ does not die quickly when it gets out in

the environment. Here apparently we have another disease organism, the virus of infectious hepatitis, which does not die readily, and, since that is so, we have reason to believe that it can be transported in the environment.

We come to the question which is most interesting to you men—namely, *"How is it spread? Is it spread by water?"*

We have reason to believe that it can be spread in various ways, that it can be spread from person to person, that the virus gets on the fingers of individuals or on things which they are handling, that it can be spread by close contact. In some instances, perhaps, it can be spread because the virus may get into the upper respiratory tract and be breathed out like the measles virus, and if you breath the air in the immediate vicinity of the person who is ill you may pick up the virus. That is a little hard to predict. Probably it cannot be spread as quickly in that way as in other ways, as the typhoid germ is usually not spread that way. We think the typhoid germ usually comes through water or milk or on inanimate objects rather than being passed by getting in close proximity to a person who is ill. We believe that it is all right even to put a typhoid patient in a ward with another patient and, if we observe sufficient precaution, that the other person does not get the disease. It is, therefore, hard to pass it through the air.

It is probably true that this disease of infectious hepatitis can be more easily spread by a person using a glass which is not properly sanitized and the next person picking it up and drinking from the same side. That would be much more frequent than passing it through the air.

We have reason to believe, then, that infectious hepatitis can be spread by water. What information have we that it is? Not a great deal of information, because you can see that we have not been so interested in this disease because it is mild, and yet over a period of forty or fifty years there are three or four hundred outbreaks of infectious hepatitis recorded in the medical literature. Among those papers you will find a few epidemics in which water has been suspected as the method of transfer; in other words, food, milk, contact and other methods did not seem to be the answer to the question of how this disease was spread in those epidemics, so that the investi-

gator has fallen back upon water as the probable thing which had spread it in that particular outbreak.

One outbreak, reported in 1931, in Canada, by a man named Fraser, was suspected to be water-borne; another outbreak, reported in 1942, in Sweden, was suspected to be water-borne.

In 1945, Neefe and Stokes of Philadelphia reported an outbreak of infectious hepatitis in a summer camp, in which they brought forward a great deal of information to indicate that it was spread by water in that particular outbreak. Just a few brief details in regard to this outbreak may be of interest to you.

This was a summer camp accommodating both boys and girls. There were 573 campers, made up of 265 girls and 308 boys—more boys than girls. On the third day after the camp opened a woman on the girls' side came down with infectious hepatitis. Three and a half weeks later a woman living in the same house came down with the disease. Five weeks after the first case there was a group of cases, fifteen or twenty cases, which occurred on the girls' side, and a week later several cases occurred on the boys' side of this camp.

Now, the two sides were somewhat separate. They each had their own dining-room. All the girls ate in one dining-room and all the boys ate in another. There was a mixing, of course, in social and athletic events daily, so that there was possible contact between the individuals, either hand to hand or other methods of transfer. You can't eliminate those methods of transfer entirely. But it was interesting that all the food came in on the boys' side and was distributed from there to the girls' side. When the girls wanted some food supplies they went over on the other side for it. The flow was in that direction so far as food supplies were concerned.

On the other hand, although there were two wells, one on the boys' side and one on the girls' side, the well on the boys' side did not produce enough water, so that almost daily it was necessary to pump some water from the girls' well into the boys' well.

The cesspool which took care of the house in which the first case occurred was just 150 ft away from the girls' well. This well was 220 ft deep. The area had about one to six feet of topsoil, and then it went down through hardpan, which was said to be just red shale and limestone. We all know that limestone tends to have crevices

in it, so that there can be more or less seepage of water down to the lower levels.

The infirmary which took care of the first batch of cases on the girls' side was also on the same cesspool, 150 ft away from the well. The three other cesspools were from 75 to 180 feet away, in a kind of ring around the well. It is supposed the sewage got into the well from one of the cesspools, probably from the one at the first house where a case occurred. The girls were the first ones to get sick, and the boys later became sick because they were using the water from that particular well. No samples of water were taken from that well at the time, because the camp closed very shortly after the investigation was begun. The larger part of the investigation had to be carried on after the individuals had returned home, so that some of it was done by mail and some done by calling on the individuals who had gone back to Philadelphia.

They attempted at a later date to prove that this water actually contained the virus of infectious hepatitis. They collected water from the well and gave it to volunteers. Nobody got jaundice. They developed some of the symptoms which you get during the early stages of infectious hepatitis but they did not get jaundice, so that it is debatable whether they had received the virus of infectious hepatitis in the water samples. Neefe and Stokes think they did; there are other people who think they did not. It is a debatable question. But these two observers have added a great deal to our knowledge of infectious hepatitis because they had plenty of material with which to work, plenty of human volunteers who were willing to act as guinea pigs, so that they might do several experiments. They took blood serum and feces both from the early cases and from the secondary cases which occurred later, and with this material they were able to produce jaundice and get a complete picture of infectious hepatitis with the feces, with the blood serum, and with some of the other materials, which you can read about in the Journal of the American Medical Association. I will not go into that further.

They carried out one additional experiment in which you will be interested. They took feces from some of these cases and added 55 ppm to two large samples of water. Volunteers took large quantities of one of these samples and two persons out of five developed infectious hepatitis.

They treated a portion of one of those samples with chlorine, 1 ppm, and two out of five who took that water developed infectious hepatitis.

They treated another sample with 15 ppm and no person out of five who drank that water developed infectious hepatitis.

I am told that they have carried on some further experiments since then—I don't believe it is in the literature yet; I have not seen it—in which they have done a better job on these experiments.

We have good evidence here, therefore, that the virus can live in water. This water was kept a number of days, longer than would be necessary for human contamination to get down through the water supply to an ultimate consumer.

They did not do some things, however, which we would have been interested to see them do. They did not prove that material from this cesspool could actually get into the well by using a high concentration of salt or a dye in the cesspool. Probably they will do that yet. So that what we have, then, is a lot of good, circumstantial evidence that this particular outbreak was spread by water. We need to have some more studies along similar lines to convince us thoroughly that this was what actually happened.

These investigations on infectious hepatitis have given us another good reason for keeping our sewage and our water supplies in different pipe systems.

Discussion

A Member. You mentioned that virus was found in the feces but you did not say "Yes" or "No" in regard to the urine. Was there a change found in that?

Roy F. Feemster. I did not record it. I believe that one out of five did get it. I am sure that you would find it if you did enough experimentation. There was much more experimenting with the feces than there was with urine, because apparently the virus is of a much higher concentration there than it is in the urine.

A Member. What about the use of filters?

Roy F. Feemster. Like many viruses, it might have clung on to the sand and other materials. There is a great loss of virus when we pass materials through a Seitz filter or a Berkfeld filter or a Cham-

berlain filter, which are the filters bacteriologists use in the laboratory to separate bacteria from the viruses. We can always get some virus through those filters. Often we would have a great concentration of virus in the material to be filtered in order to get some through. I have not seen any experiment yet to show just how much a slow sand filter or a rapid sand filter would take out, but I am sure that some would go through the sand filter.

HAROLD W. GRISWOLD (Hartford, Conn.). Can anyone answer that question on the rapid sand filters? I think on the slow sand filter you would get very little through because of the gelatinous material which collects on the surface.

ROY F. FEEMSTER. It is a very small organism; it goes through the pores of very fine laboratory filters and might go through biological layers of slow sand filters.

HAROLD W. GRISWOLD. I understand. I was a little bit surprised that in a camp of 500 people the state of Pennsylvania is without supervision as to the water supply. Is that a customary procedure in Pennsylvania, do you think?

ROY F. FEEMSTER. I don't know very much about how close supervision they have there.

HAROLD W. GRISWOLD. I know in the New England states it would be impossible to run a camp of that size without proper supervision by the state.

ROY F. FEEMSTER. Not an impossibility but they would find us on their trail making recommendations and so forth.

HAROLD W. GRISWOLD. I think it is pretty nearly an impossibility. The principal thing that struck me was that it requires a much larger dose of chlorine than any of us are putting into our water supplies to kill this virus, so that we have no protection, so far as chlorine is concerned, against this. The only way we can escape it is to keep the carriers off the reservoir, which is another argument for not using our reservoirs for fishing and recreation.

A MEMBER. Can you actually buy a miscroscope with which you can see these organisms?

ROY F. FEEMSTER. No.

THE MEMBER. In other words, to get at the virus, if it is in the water—

ROY F. FEEMSTER. You have to get the human volunteers.

A MEMBER. Can't you see them with the new electro-microscope?

ROY F. FEEMSTER. You could not distinguish it from other particles of similar size.

A MEMBER. Has any work been done to determine the result of oxidizing agents?

ROY F. FEEMSTER. There has been very little done on that, I think. I think this one paper has reported more of interest than any others at the present time. I imagine that there will be a great deal of work done on it in the immediate future, because it has gone up very much in interest.

SANITATION AND PUBLIC-HEALTH EXPERIENCES IN EUROPE

BY LEONARD W. TRAGER*

[*Read January 10, 1946.*]

As the title of this paper suggests, there will be given some of the writer's experiences in the field of sanitary engineering, general sanitation and public health in Europe. These experiences were had in Sicily, the southern part of Italy, Sardinia, all of southern France and in the State of Wurttemburg in Germany. Because the writer's past experiences have always been with a State Health Department, things and conditions found will be reported in this paper as seen through jaundiced eyes.

Sanitation in Sicily. At one time or another nearly everyone has heard something about the sanitation or the lack of it in Sicily. This can best be described in a copy of a poem picked up in Palermo.

PANORAMA OF SICILY

If I were an artist, with nothing to do,
I'd paint a picture, a composite view
Of historic Sicily, in which I'd show
Visions of contrast, the high and the low.

There'd be towering mountains, a deep blue sea;
Filthy brats yelling "Caramella" at me;
High-plumed horses, and colorful carts;
Two-toned tresses on hustling tarts.

I'd show Napoleonic cops, the carabinieri;
Dejected old women, with too much to carry;
A dignified gentleman, with a "Balbo" beard;
Bare-bottomed bambino, both ends smeared.

Castle and palace, opera house, too;
Hotel on a mountain, glorious view;
Homes made of weeds, brick-bats and mud;
People covered with scabs, scurvy and blood.

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Fine old homes, pride of the nation,
Beautiful to see, but no sanitation;
Well-equipped schools, without a scholar,
Temples of learning, surrounded by squalor.

Chapels and churches, great to behold,
Each a king's ransom, in glittering gold;
Poverty and want, men craving for food,
Picking through garbage, practically nude.

A hill-top village; a walled-in lane;
Grimy old hags, all twisted with pain;
Beautiful image, most blessed of mothers;
Scalped monks and alms-asking brothers.

Stately cathedrals, with rich-toned bells;
Ricovero shelters, with horrible smells;
Mouldering catacombs, a place for the dead;
Noisy civilians, clamoring for bread.

Palatial villas, with palm trees tall;
A stinking hovel, mere hole in the wall.
Tree-fringed lawns, swept by the breeze;
Goats wading in filth, up to their knees.

Revealing statues, all details complete;
A sensual lass, with sores on her feet;
Big-busted damsels, but never a bra,
Bumping against you, there should be a law.

Sweeping boulevards, a spangled team;
Alleys that wind, like a dope fiend's dream;
Flowers blooming on the side of a hill;
A sidewalk latrine, with privacy nil.

Girls with shoes, soles two inches thick;
Unwashed peddlers, whose wares make you sick;
Grapes, lemons, postcards and nuts,
Dolce and vino, to torture your guts.

Two-by-four shops, with shelving all bare;
Gesturing merchants, arms flailing the air;
Narrow-gauge sidewalks, more like a shelf;
Butt-puffing youngster, scratching himself.

Lumbering carts, hogging the road;
Nondescript trucks, frequently towed;
Diminutive donkeys, loaded for bear;
Horse-drawn taxis, seeking a fare.

Determined pedestrians, courting disaster,
Walk in the street, to clean the brick;
Bicycles and pushcarts, blocking your path;
Street-corner politicos, needing a bath.

A crowded train, with fares in the cab,
More on the cow-catcher, breeding a scab;
Miserable buses, which move with a grind,
Packed to the roof, more left behind.

Arrogant wretches, picking up snipes;
Miniature Fiat, various types;
Young street-singer; hand-organ tune;
Shoe-shine boys; a sidewalk saloon.

Garbage-strewn gutters, reeking with stench;
Weather-beaten beggar, a God-awful wench;
A boy on the corner, yelling "Gior-nal-e,"
A half-dressed urchin, fly-covered belly.

Barbers galore, with manners quite mild;
Prolific women, all heavy with child;
Duce's secret weapon, kids by the score,
Caused by his bonus, which isn't no more.

No birth control in this fair land;
One child in arms, two by the hand.
Page Margaret Sanger, just turn her loose,
Her gospel is needed; put it to use.

A beauteous maiden, a smile on her face,
With a breath of garlic, fouling the place;
Listless housewife, no shoes on her feet,
Washing and cooking right out in the street.

Elegant cassets, carved out by hand;
Odorous factories where leather is tanned;
A shoemaker's shop; a black-market store;
Crawling with vermin, no screen on the door.

No sense of shame has the soliciting boy;
Unfortunate children with nary a toy;
Pathetic monstrosity, the hunch-back dwarf;
Oil-strewn seashore, craft rotting at wharf.

I've tried to describe the things I have seen;
A panorama of Sicily, the brown and the green;
I've neglected the war scars, visible yet,
But these are the things we want to forget.

I'm glad I came, but damn-anxious to go;
Give it back to the natives, I'm ready to blow!

A Case of a Milk Supply. As to milk supply and its distribution, here again its rudimentary nature does not appeal to Americans. In Sicily there is a belief, which may or may not be true, that the cows will not give milk unless a calf is sucking. It was not an uncommon sight to see a cow driven down the street and halted in front of the home of a customer, the dairyman milking such quantity as was needed to fill the proffered container, and at the same time a calf sucking at the other side of the cow. In going to the next customer, it was not infrequent that the dairyman and the calf would change sides for the next milking. The measure into which the milking was done was carried in the side coat-pocket and, after each milking, more grease, dirt and stain were added to the garment, not to mention more contamination into the container and into the milk as delivered.

Sewage Disposal. In some of the smaller cities of Sicily, the sewerage systems, treatment and final disposal of sewage were as rudimentary as the cases above regarding milk. In one case, the sewerage system was found to have been laid directly under the houses along both sides of the street. Under a removable door in the floor of each house was an inverted siphon. The lower, or down-grade, end of the siphon was open to permit its use as the family toilet. Water for flushing depended on someone up the street pouring dishwater or other liquid waste into the line. As can be seen, each of these siphons would act as a small septic tank and, insofar as odor was concerned, the condition was progressively worse along the line. Finally, the sewage would reach the valley near the stream and at this location the sewage would be stored in open wells or reservoirs. From these

reservoirs, the sewage would be pumped into canals for final disposal onto garden land. Because of the small quantities of sewage contributed to this sort of a system, there were times when diluting water was allowed to run into the wells from the stream.

The application of night soil or sewage onto the land is a common practice, not only in Sicily but all over Europe and Africa. However, the carelessness and lack of thought as to where these materials were deposited or applied seemed to be worse in Sicily. On one of the water supplies for Palermo for instance, a considerable amount of night soil was applied directly over the water supply galleries. The cover of more or less porous rock and soil over these particular galleries was only three to four feet in depth.

Water Supplies. For the most part, the water supplies in Sicily and southern Italy were obtained from galleries drilled into the side of hills and mountains, always located many miles from the cities or towns to be served. The galleries are simply tunnels cut through the rock. On one side of the walkway in the tunnels there is a rather deep channel while on the other side there is a narrow, shallow one with occasional pipes laid under the walkway to carry the water into the larger collecting flume. At various points along the main gallery there are smaller feeding galleries which radiate in various directions. From these systems of galleries the water is brought to an underground reservoir and then piped to the city or town. Credit must be given this sort of system because all these waters afforded excellent physical and chemical analyses and at times excellent bacteriological analyses at the sources, as well as at the distribution reservoirs, always covered.

The main criticism on practically all supplies in Sicily and southern Italy is that they are usually located long distances from the cities. The main supply lines from the sources to the distribution reservoirs are generally undersized and, finally, the quantity of water available or delivered is generally insufficient. These faults are reflected in the final bacteriological analyses as taken in the distribution system. The reason for these differences is that for a period of about twelve hours each day, the water is turned off from the distribution system, allowing back-siphonage and thereby permitting the entrance of considerable pollution.

Why the source of supply was always located great distances away can be explained partly by the system of government and management. The Civil Engineer for the Province received part of his pay on a percentage basis. In other words, if a water system was to be installed the duty of employing and paying for the services of a consulting engineer, the approval of the plans and the letting of the contract was always the responsibility of the Provincial Engineer. Naturally, then, when part of the engineer's pay depended upon a percentage of the construction costs, he would, within limits, insure that the total cost be built up.

Except in the best and most modern of homes, in Sicily, Italy and in certain communities in France, there is no such thing as water service as we have it. Instead, the common resort is to public fountains installed conveniently in the streets. By "fountains" is strictly meant running water through small spigot hydrants. In an effort to cut down on this enormous water wastage through a constantly running fountain or hydrant, there were installed, in certain places, spring-loaded valves, so that when not compressed the water would automatically shut off. In most cases these valves were torn off by the users because of the belief that the water was unfit to drink if not kept running. Another reason for not wishing to hold a valve open to fill containers was that it would prevent him or her from talking because both his arms could not be put to use for emphasis.

Water Analyses and Records in Sicily, Italy and Sardinia. Without exception, none of the laboratories visited by the writer have ever had a regular water-sampling schedule for all the supplies within the province. Certain few of the laboratories, however, have made periodic tests on the supply serving only the provincial capital, the city in which the laboratory was situated and the principal city in the province. In general, the only samples that were submitted for analysis were those specifically requested by the Medico Provinciale and then only when the supply was suspected of being responsible as the source of an epidemic. As a result, the few analyses that were made were insufficient to provide a dependable record on which to judge the potability of the supplies. Lack of adequate transportation, not only during the war but in the past, was given as the reason for this deficiency.

In addition to the infrequency of water analysis, another most glaring deficiency was that of the great variety of procedures and methods employed in the various laboratories. There was no pretense at standardization and in some cases the results obtained were of little or no value at all.

Laboratory equipment and materials, such as incubators, sterilizers, autoclaves, pipettes, Petri dishes, fermentation tubes, bacterial media, etc., are, for the most part, of good quality and design but are not adequate to perform a large-scale sampling program.

As a result of the war, some laboratories were unable to do any work at all, because no heat was available to operate the sterilizers or for other laboratory uses.

In checking through the journals in which all analyses were recorded, a high percentage of the waters were found contaminated. From these records one could reasonably cast aside all doubt that certain supplies had been responsible for some of the typhoid-fever cases reported. Whether the contamination came from the source of supply directly or whether it came as a result of back-siphonage, when the supply was shut off, was not known. It was presumed, however, that the greater part of the contamination resulted from the latter procedure.

Protection for Our Armed Forces. Because the water systems were, for the most part, antiquated and the local public health programs and procedures were far below our recognized standards, we could not take time, nor could we expend money and materials, to provide adequate educational programs to bring these things into line. Our procedures were simple—*i.e.*, we placed the responsibility upon the unit commanders, who in turn were made to require chlorination of all water used by the troops.

Water Treatment. In southern Italy and Sicily the writer did not find any water treatment plants other than chlorination and even these could not truthfully be classed as such. Chlorination when it was employed was simply a procedure of applying minute doses of hypochlorite through a drip-type apparatus. The quantities of chlorine added were always so small that no residual with ortho-tolidine could be obtained. A small number of these installations was found.

In Sardinia, a much different situation was found with regard

to treatment. Here the larger cities employed filtration of both good and bad design.

The supply for Sassari is obtained from two impounded reservoirs. The water-shed is approximately 7.0 sq mi, the larger part of which is under cultivation. In addition, three-quarters of the small village of Osilo is on the watershed. The capacity of the reservoirs when full is approximately 125 mil gal.

The filter-plant capacity was estimated to be 500,000 gal per day, which had to serve the 55,000 civilian population as well as a large number of Italian soldiers. On this basis, less than 10 gal per person per day was supplied. Because of the insufficient quantity produced, it was only natural that the system be shut off 12 to 16 hours every night.

Following the step aerators the water is put through coagulation basins. The alum dosage was set at 2.9 grains per gal. When the authorities were questioned as to the pH values of the raw and filtered water, they answered that it was 8.8 before and 5.0 after. Because the floc was forming late, much of the alum was carried over into the six preliminary filters, which are piped in series. These preliminary or roughing filters had a filter medium of ⅛-in. diameter gravel, laid to a depth of 4 to 6 in. It was obvious that whatever excess floc was carried over from the coagulation basin would be broken up in passing through these filters and the four kilometers of pipe line leading to the secondary or final filters. When the water reached the final filters, the color removal had not been complete and there was no evidence of any floc remaining.

At the final filtration plant there were two separate units, the first of these having about 40 cm of coarse sand. As the water entered the plant, it was piped to the first set and then to the second series of filters, which had 30 to 40 cm of very find sand. The effluent from the last set of filters appeared to be clear but, as expected, the rate of flow was exceptionally slow.

Damage to Water Supplies and Sewerage Systems in Southern France. In the invasion of southern France, the greatest amount of damage done to water and sewerage systems was from pre-invasion bombing. Following the actual landing operations, practically all the damage to these systems resulted from the blowing of bridges by the

retreating elements of the German Army. One exception to this resulted from ground operations, which caused damage to the system of electrical transformers at the pumping station in Toulon. The repair to this was accomplished by the water-supply engineers of the 7th Army.

In most instances during a fast-moving offense, such as was the case in southern France, the local water authorities had repaired all the lines, damaged as a result either of bombing or of blown bridges, in a relatively short time without help or aid from outside. However, there were instances where aid became necessary. One of these places was Avignon (Vaucluse). At this place the main supply main from the source to the city parallels the railroad yards for a considerable distance. Sections of this pipe line were destroyed on three different occasions. A stockpile of pipe was on hand to repair the line after the first two bombings but, after the third bombing, no more pipe of adequate size was available. At Cete (Herault) there were about 4 kilometers of the required 800-mm pipe but the local officials refused to release the 150 meters for Avignon. This matter finally had to be turnd over to the proper French authorities for action.

Another instance where the U. S. Army authorities took a hand in providing assistance was in the city of Arles (Bouches-du-Rhone). By destroying all the bridges across the Rhone River, we were able to isolate the elements of the German Army on one side from helping those on the other. In bombing these bridges we also damaged some of the nearby buildings. Unfortunately, the water filtration plant at Arles was too near one of the railroad bridges and was also destroyed. This bombing occurred before the invasion of southern France on August 15, 1944. On September 11 an emergency supply taken directly from the Rhone River was started. An emergency pump was salvaged from the wrecked plant and a Wallace & Tiernan chlorinator was installed. According to the local authorities a new plant could not be completed in less than two years.

Operation Personnel in Water Treatment Plants. In southern France, as well as in Sicily, Italy and Sardinia, operating procedures in water treatment plants are not comparable to those practiced in this country. The care, supervision and general knowledge given to or possessed by the operators is very limited. This fact is shown, in

part, by the vital statistics of these countries as related to typhoid fever. Not one instance was found by the writer in any of the above-mentioned countries where a chlorinator was properly operated. Chlorine is applied at a specific rate to meet the chlorine demand found in one test sample. No excess chlorine is added and no excess tests are taken.

Shellfish. Although it was known by the French public-health officials that the use of shellfish taken from practically all areas in the Mediterranean is a dangerous practice, they allowed the taking and the selling of these products on the open market. They did this to increase both the amount and variety of food for consumption in the coastal areas, thinking that the increased food would be preferable to a few scattered cases of typhoid fever.

Typhoid Fever. In all the Mediterranean countries the incidence of typhoid fever is extremely high and much of it is taken for granted. To us in this country, such a rate would be alarming. For the seven southeastern provinces of France, which include the Riviera, 133 cases of typhoid fever were reported for the month of July, 1945. Toulon, which is not a large city (about 30,000 people) had 31 cases in this period. At the same time Marseilles, which has a population of 750,000, had 37 cases. This figure is not necessarily high for Marseilles, because at times last winter reports showed nearly that many cases in any given ten-day period. When the French authorities were questioned as to what they were doing about the apparently high rate of typhoid fever they would answer, "Nothing, the rate is normal."

In regard to typhoid fever and design, operation and maintenance of water supplies in all the above-mentioned countries, there is no doubt that a reduction in the rate could be made, if a reasonable number of sanitary engineers were employed by the governments similar to the system practiced in this country. In all my travels through these countries I did not meet even one sanitary engineer employed by a governmental agency. For that matter, very few public-health inspectors were met.

The Riviera. With all the beauty of the Riviera and the reputation that this area has for being the world's most noted playground, there is still much to be desired in the fields of public health and

environmental sanitation. Whatever the deficiencies are, they can be blamed in large measure on both the public-health officials and the lack of appreciation of basic public-health principles by the public. The situation with regard to the taking and selling of oysters has been mentioned. The lack of treatment of a public water supply derived from a surface source and supplying one of the cities is one glaring fault. The use of ozone treatment in an area where power failures or shut-offs are frequent is another. Finally, to allow the continuance of discharges from 17 sewer outlets onto or near the bathing beaches for one of these famous cities is a thing our own people would not tolerate.

Germany. For the most part, the deficiencies noted in the countries to the south did not exist in Germany. However, our saturation bombing, causing thousands to be homeless, and the prevalence of louse-borne typhus among both civilians and displaced persons were our biggest problems in the American-occupied zone of this country. The last week the writer was stationed in Germany, 19 cases of typhus were reported in this particular zone of responsibility. Half of the above cases were among the civilians, while the other half were in displaced-persons camps. To bring this epidemic under control, DDT was used in 10% powder form, blown or dusted on the clothes of all the people in the camp or in the homes. Immediate dusting brought the epidemic under control in an exceptionally short period of time.

Conclusion. This paper covers only part of the writer's activities and experiences but, as will be gathered, he was not too impressed with the things and conditions found. In the matter of public health, as well as in practically everything else, those countries are far behind us, a thing that was realized by practically all our troops and that gave them a real sense of pride in their own country.

WATER SUPPLY IN THE ASIATIC-PACIFIC THEATER

BY EDWIN B. COBB*

[*Read January 10, 1946.*]

THE purpose of this paper is to describe briefly the various problems in water supply encountered by the Navy at its bases in the Pacific and Asiatic areas.

The writer was commissioned in the Civil Engineer Corps of the U. S. Naval Reserve on October 12, 1943. He was first assigned to Construction Battalion Maintenance Unit 588 as Executive Officer and later as Acting Officer-in-Charge. With this unit he was stationed at Canton Island in the Phoenix Group, located near the Equator in the Central Pacific. In March, 1945, he was transferred to the staff of Commander, Service Force, Pacific and assigned to the Engineering and Construction division of the Advanced Base Section, stationed at Pearl Harbor.

With Lt. Commander Paul H. Peterman, CEC, USNR, formerly with the Chicago Board of Water Supply, and later assisted by Lt. Commander Ralph W. Peterson, CEC, USNR, formerly assistant superintendent of the Calumet Sewage Treatment Plant of Chicago, the writer took part in setting up a consulting service to assist with the solution of problems concerning water supply and sewage disposal in the Pacific Ocean area and to plan for future assaults.

The writer also had considerable contact with the problems arising from the operation of distillation equipment for advanced bases. He spent a month in the Gilbert-Marshall area, studying the water-supply and sewage-disposal problems therein. In October and November, 1945, he visited China and reported on the availability of water supply for the fleet at the major ports along the coast.

PACIFIC ISLANDS

Hawaii. The Hawaiian Islands have been a major bastion in our war in the Pacific and have experienced a tremendous military development. Fortunately the Island of Oahu, on which Honolulu is

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located, is blessed with an excellent source of water. Nature has provided a large natural reservoir in the form of pervious rock strata, which are exposed in the mountains and which extend below the city out under the ocean. A blanket of impervious soil covers the pervious rock along the coast and the only escape for the fresh water is into the sea at a depth of 1500 ft. At present the fresh water in the basin stands about 20 ft above the sea level and, according to the Ghyben-Herzberg* theory, the fresh water should extend 800 ft below sea level. The artesian water, or water floating on the salt water, is known as "basal" water, to differentiate it from perched water in the mountains. The mountains on the island cause rising air currents in the moist trade winds and heavy rainfalls result, which replenish the water supply.

In 1938 the total draft from the artesian source was 31 mgd but in 1944 it increased to 67 mgd, including consumption at Pearl Harbor. The manager of the Honolulu Board of Water Supply estimates that the present draft by the city is equivalent to what had been expected with normal growth in 1965.

A large proportion of the Honolulu supply is now obtained from tubular deep wells but it has been found that this type of well when over-exploited becomes contaminated with brackish water. To overcome this difficulty, a special type of well known as the "basal" type well has been developed. This well consists of a vertical or sloping shaft extending from the ground surface to sea level. At the bottom the shaft is enlarged to form a pump chamber and is carried a few feet below sea level to provide a sump for the pump suctions. If the yield from the shaft proves insufficient, tunnels are excavated laterally, with their inverts at an elevation about 2 ft below sea level. With such a well it is possible to develop the maximum yield from the ground with little danger of salt-water contamination. The City of Honolulu now operates three "basal" water wells and expects to construct three more in the future. The Navy has two such wells in the Pearl Harbor area. The perched mountain water has been highly developed but furnishes only a small percentage of the total supply.

The principal need at Oahu is for a water administrator to allocate fair amounts of water to the City, to the Armed Forces, and to

*Tolman, C. F. Ground Water, p. 543.

the commercial interests, so as to prevent the depletion of the artesian supply. Without its water supply Oahu would have little value as a military base.

On the island of Hawaii at Hilo the Armed Services developed a large airfield. Two dug wells were constructed on the grounds of the airfield but one of these wells was not too successful. Considerable difficulty was also experienced in getting the proper pumping equipment. As a consequence, the airfield has depended upon the City of Hilo for its supply of water.

Hilo obtains its water from the Wailuku River, which rises high on the slopes of the volcano Mauna Kea, west of the city, and from perched springs, also on the mountain slopes. The demand of the airfield for water has been large and as a result pressures in the city have been reduced below those desirable. Fortunately no drought occurred during the years of the war; otherwise serious difficulties might have arisen.

Central Pacific Islands. The Navy developed a great many bases on the atolls of the Central Pacific. The typical atoll is roughly ring-shaped and has a limited land area, which averages six feet in elevation above sea level. Water supply on these islands may be divided into three categories, namely: collected rainwater, fresh ground water floating in lens-shaped bodies on the salt ground water, and distilled sea water.

Rainfalls up to 160 in. per year are reported at some islands and in many instances collected rainwater greatly augmented other forms of water supply. At Palmyra Island, the first stop on the Honolulu-Australia air route and an important base during the early stages of war, rainwater formed the principal source of water supply. During a visit to Eniwetok in July, 1945, the writer lived in a Quonset hut, the roof of which was adapted to rainwater catchment. A small, elevated wood tank was used to store the rainwater. At the end of a week's stay, during which about ten officers took daily showers and used the water in lavatories, the storage tank was as full as when the writer arrived. At Kwajalein rainwater was collected by several outfits but was so highly contaminated by the dust which had settled on the roofs during dry periods that the medical officer condemned it for bathing or similar uses.

In general, due to the lack of sufficient piping, storage tanks and the necessary labor for installation, rainwater catchment areas were not developed as fully as might have been the case. In peace-time installations at a number of the atolls it should be possible to derive the entire water supply from rainwater catchments.

Previous to the war the natives on many islands derived their water supply from shallow wells by skimming off the fresh water floating on the salt water. Where fresh water was scarce, the natives developed a tolerance for water containing a degree of salinity which would be disagreeable to most of us. Because the amount of ground water available on most islands was generally small and what little there was had usually been over-exploited by the first arrivals, ground water was a relatively unimportant source of water supply.

At Kwajalein, brackish ground water was used for showers but was not very popular because of the difficulty of getting clean with such water. Some outfits reported skin eruptions following continued use of salt-water soaps. At Eniwetok, the terrific bombardment of the assault is said to have destroyed what little fresh ground water was reported as formerly available.

The distillation of sea water was the most common method of water supply on Central Pacific islands. Early in the war the Navy more or less standardized on a portable, double-effect evaporator manufactured by the Cleaver Brooks Company. This proved to be a very fortunate choice. These units are rated at 5,000 gal per day for 20 hours' operation; however, except in rare instances, 4,000 gal per day was generally the maximum available production. In this unit a gasoline engine drives the cold-water pump, the hot-water circulating pump, and the oil-burner blower. Diesel oil is burned for fuel and approximately 18 gal of water are produced per gallon of fuel oil burned. The gasoline-engine driving unit consumes about 1 gal of gasoline per hour.

Some of the distillation units were equipped with continuous blowdown for removing the concentrated salts but the older units required manual operation of the blowdown. The distillate cooler and condenser tubes required cleaning of salt scale every 18 days, the second-effect coils every 36 days, and the first-effect coils every 3 months. Cleaning was generally done manually, by reaming the tubes

and cracking the scale off the coils by means of a blow-torch. Chemical cleaning was found to be successful but the required chemicals were generally unavailable. A program to use boiler compound or corn starch to prevent the formation of hard scale was inaugurated just before hostilities ceased. Similar treatment had been found extremely effective with shipboard evaporators.

The double-effect unit was very rugged and easy to repair. Where power was available, electric-motor drive was substituted for the gasoline-engine drive, resulting in greatly reduced maintenance. The writer saw distillation units that had been badly abused and neglected which continued to produce fresh water. The second effect of one such unit was found to be almost filled with salt scale.

In an effort to save fuel, the Navy later changed from the double-effect unit to a vapor-compression type of distillation unit. In this unit a vacuum is created over the heated water in the boiler, causing it to give off steam at a temperature less than the normal boiling point. In turn, the compressor added heat to the steam by mechanical effort, which heat was transferred to the incoming salt water by the condenser. Aboard ship, where auxiliary heat was available and where the unit was properly laid out to facilitate cleaning, the vapor-compression type was quite successful. With the unit developed for advanced-base use, a gasoline engine was employed to drive the compressor and to circulate the salt water. The engine-jacket cooling water was used as the source of heat.

Due to shortages of materials, poor engineering and the desire to obtain a maximum efficiency, some advanced-base-type units as developed proved to be rather unreliable. Production of nearly 100 gal of water per gallon of gasoline was claimed but under atoll conditions could seldom be obtained. Experience with this type of unit at the islands indicated that the gasoline-engine driving units were underpowered, which, coupled with the high temperature of the sea water, caused the engines to overheat. The machines were also very sensitive to changes in air temperature and it is reported that a sudden draft striking a unit would cause it to go out of production. To improve heat-exchange efficiencies, thin-shelled tubes were used in the condenser and distillate coolers and, as a result, those tubes were easily pierced during hand reaming while cleaning. Chemical cleaning

was practically required but the supply of cleaning chemical was uncertain. The operation of the units demanded the services of high-class mechanics to keep them running and many of the smaller outfits did not have this type of skilled personnel available.

The transition from the old units to the new was well under way before the shortcomings of the new units were recognized. The procurement of spare parts for the old machines was halted, which caused great difficulty, because the old machines remained the backbone of the water supply. Fortunately the older machines responded to "baling wire" repairs and the war stopped before serious consequences developed.

It is expected that for peace-time operation low-pressure multiple-effect distillation units, similar to shipboard units, will be used. These units are too cumbersome, however, for portable equipment.

Marianas. In later phases of the war the islands of Guam, Saipan, and Tinian supplanted Hawaii as the principal Pacific base. Unfortunately these islands are not provided with an abundant water supply such as is available at Oahu. The rainfall at the islands is adequate but ground-storage conditions are unfavorable, due to the large proportion of impermeable rock present.

A water-resources survey party, composed of Lt. Commander Paul H. Peterman, CEC, USNR, Mr. Frederick Ohrt,* Manager of the Board of Water Supply of Honolulu, and Dr. C. K. Wentworth, the geologist of the Honolulu board, visited the islands during early 1945 and laid out a policy for water-supply development. Three types of development were proposed, namely: development of the upland springs by tunneling, construction of basal-type wells where feasible, and the construction of deep wells not to extend more than 15 ft below sea level.

The naval construction forces completed the necessary tunnels and deep-well holes quickly but delivery of pumping equipment was so slow that it is possible that some projects have not even yet been completed. Fortunately the existing available supplies were sufficient to meet the minimum requirements of the military forces through the period of major activity.

Iwo Jima. Iwo Jima, or Sulphur Island, is estimated by Dr.

*Member of this Association.

Wentworth to be not over 1000 years old and there is still considerable volcanic action in the area. It has been reported that the ground heat in certain locations is so intense as to make fox holes untenable. The gasoline in one pipe line crossing a hot area heated up sufficiently to vaporize, making it necessary to cool the gasoline before fueling planes.

Rainfall at the island was plentiful but storage conditions were unfavorable, due to the impervious igneous rocks present. The sandy neck leading to Mt. Surabachi provided a limited source of fresh water but this was soon exhausted. A number of wells were constructed but nearly all yielded hot, highly mineralized water. One analysis of the well water indicated an iron content of 10 ppm. Various attempts were made by the garrison forces to treat the water but to no avail and distillation of sea water continued to be the principal source of potable water. The well water was employed for bathing but had to be cooled before it could be used.

China Coast

In October, 1945, the writer was ordered on temporary additional duty with Commander, Service Division 101, to report on the availability of water to supply the 7th Fleet at ports along the China Coast. Shanghai, Hong Kong, Tsingtao, Tientsin and Peking were visited.

Hong Kong. Hong Kong is a British Crown Colony and is reported to be the only British colony to show a profit. The city is located on an island which is rather mountainous. Across the bay on the mainland is Kowloon, which accommodates the overflow of population from Hong Kong. Before the Japanese occupation there was a large European population in the city and many fine mansions were built in the surrounding hills.

It is interesting to note that the English firm of Binnie, Deacon & Gourley were consulting engineers for the Hong Kong water works prior to the war. Mr. Binnie is an Honorary Member of the New England Water Works Association and Mr. Gourley gave a paper at the 1936 convention of the Association.

There is no natural water supply available at either Kowloon or Hong Kong but the British dammed a number of the valleys to form

reservoirs and stored the runoff from the surrounding hills. Rainfall distribution is poor, being concentrated in a few months each year, and on occasion in the past the city has experienced water shortages. As Hong Kong grew, the available area on the island was exhausted and reservoirs were built back of Kowloon. The water is piped across the bay to Hong Kong.

All the water is treated by filtration, the older plants being of the slow sand type and the newer plants of the rapid sand type. Before the war, the water works were credited with producing a good water. Published records, however, indicate that the results were slightly inferior to those at Shanghai.

As will be remembered, the Japanese first captured Kowloon and from there shelled the Hong Kong reservoirs to hasten the surrender of the city by depriving it of water. The damage, if any, to the reservoirs was either superficial or has been repaired, for those reservoirs which the writer saw appeared to be full and in good condition. At the time of its capture by the Japanese the population of the city was over a million, being swollen by an influx of refugees, of which at least 100,000 persons lived aboard sampans in the harbor. As a result of abuse by the Japanese, lack of food, and disease, the present population is only 250,000 and only a relatively few sampans are left in the harbor. Over 100,000 Japanese were being held as prisoners of war in the area.

The Japanese built a monument on a mountain back of Hong Kong to celebrate their conquest of China. This monument was paid for in blood by the Canadians and Chinese who perished building it.

Characteristically, the Japanese paid scant attention to maintenance and the harbor was pretty well worked over by the 14th Air Force. The city now presents a desolate appearance. There are a number of sunken vessels in the harbor and the naval facilities are a ruin. Fuel has been a terrible problem and there was scarcely enough coal on hand to keep the city power plant operating. Just before the Japanese surrendered, they turned the city over to the Chinese. The latter, being desperate for fuel, stripped every building not under guard of its wood, taking the roofs, floors and the window and door frames of all the formerly beautiful mansions around the city, so that nearly all are empty ruins.

The Japanese failed to maintain the water works and neglected to wash the filter sand. When the plants could no longer put out enough treated water to supply the city, untreated water was turned into the mains.

In October, 1945, although no chemicals for coagulation were on hand, some chlorine appeared to be available. Sand was being removed from Kowloon slow sand filters, to be washed and reclaimed. The labor force on the latter project consisted of 500 Chinese women.

Fortunately the rainfall had been adequate during the months preceding the surrender of the city and the reservoirs were all full. The British had flushed out the mains on the Kowloon side and claimed to be getting a safe water at the time of the writer's visit. In Hong Kong the water had a milky appearance.

The writer drove over the reservoirs of the Kowloon system and was struck by the lack of protection at the various dams. The watershed was overrun with refugees, returning from the interior of China, who could find no quarters in the city. There were numerous evidences of fecal pollution along the borders of the reservoirs. The lack of guards was explained by a shortage of British troops and the number of Japanese prisoners who had to be guarded by the available forces.

Hong Kong appeared to be in the worst condition of any city the writer visited in China.

Tsingtao. Tsingtao is located on the southerly side of the Shantung Peninsula, north of Shanghai. In the prewar days it was the summer resort for the wealthy of Shanghai and as such was rather pleasantly developed.

Water-supply resources of the area are limited, there being no surface runoff during a large portion of the year and the ground-water storage being small. Water supply is obtained from well points driven in the gravels along the beds of the various rivers west of the city.

The initial water supply was developed by the Germans prior to World War I and was obtained from the first river west of the city. As the city has grown, the water supply has been pushed progressively farther west, and since the first system the supply has been enlarged at least twice and possibly three times. In spite of this expansion, the city is said to have experienced water shortages during many summers in the past.

Water is now obtained from a river about twenty miles to the west and is pumped to the city. Before the war, the city had a population of 600,000 but now has grown to over a million. The Chinese had received delivery of pipe to enlarge the supply mains leading to the city just prior to the Japanese occupation. However, the Japanese confiscated the pipe and shipped it to Japan.

As usual, the Japs neglected to maintain the waterworks. During the winter of 1944-1945 general lack of fuel for heating homes resulted in the freezing of large numbers of services. No attempt was made to find and repair the many leaks which developed. With the growth of the city's population and the excessive leakage, it became impossible to keep the pressures up to normal.

Just before the Japs surrendered, they destroyed all the plans of the water-distribution system. The operation of the waterworks was taken over by Chinese who have but a limited knowledge of the system. The Chinese told the Marines who occupied the city that the Japs had also stolen some of the booster pumps. The Marines have been unable to determine whether or not the booster pumps ever really existed.

The Marines were attempting to locate the main feeders and valves which control the mains, but the whole system appears to be a maze of interconnected piping and the Marines appeared to be a bit discouraged. Over most of the city there was no water available at the second floors of buildings.

Results of analyses of water from the mains showed that one sample in three was polluted. The Marines set up water points where they chlorinated water taken from the city mains and distributed it in trailer units to various points for their own use. Water with 3 ppm chlorine residual was generally found to be safe. In spite of all precautions, there appeared to be considerable mild dysentery among the troops.

Tientsin. Tientsin is located north of the Yellow River and south of the Korean Peninsula. The city is an important railway terminus and the port of entry for a large area of northern China. Actually, the city is located about 20 miles from the coast. Freight has to be lightered from ships anchored 12 to 14 miles offshore at the Taku Bar and the lighter sailed 30 miles up the Peking River to the city.

European and Chinese interests had kept the river dredged before the war but the Japanese had not bothered to do any dredging. As a result of this neglect, the river channel had become so badly silted that only craft of under 10-foot draft could negotiate the river. The Japanese had planned to make Tientsin a great industrial area and to develop a large port at Taku at the river's mouth. Actually, the projects appeared only 80% completed. Since the surrender the Chinese, in search for fuel, had stripped all unguarded structures of nearly every particle of wood.

Originally the water supply for Tientsin was obtained from the Peking River, which is heavily polluted, but during the thirties it was discovered that strata containing artesian water underlay the city at depths of from 400 to 700 ft. Actually, these strata underlie the whole area from an undisclosed distance under the Yellow Sea to nearly 200 miles inland at the Western Hills, which lie just west of Peking. In general, this water is of excellent quality, although in certain places it has shown a high mineral content, which renders it somewhat unsatisfactory for boiler use.

Each of the various concessions at Tientsin had developed its own waterworks, generally in the form of deep wells with air-lift pumps. Upon the surrender of the Japanese, the Chinese had taken over the operation of the works. In the case of the British Concession, the Englishman who was formerly engineer of the works was advising the Chinese in their operation.

The Oriental appears to have an inborn aversion to closing water faucets and the widespread wastage of water plus considerable leakage occasioned by lack of maintenance has been more than the system could supply. In general, there was no water at the second stories of most buildings and, as a result of negative pressures, nearly all tap samples of water showed pollution. To offset this pollution, the Marines had set up several points and were filtering the water and chlorinating it to 3 ppm.

The medical officers at Tientsin were engaged in making a study of the incidence of amoebic dysentery among the natives. In their preliminary work, examination of the stools of 136 Chinese coolies indicated only 5 carriers, which is less than the reported 10% in the United States or the 26% among the Marines at Okinawa. A

doctor made the remark that probably the Marines would give the Chinese amoebic dysentery.

For some reason the Chinese prefer filtered river water to artesian water, for they were planning the construction of a large water filtration plant to treat the river water in lieu of expanding the deep-well supplies.

Tientsin received but little damage from the war and the British waterworks operator reported that he had been reasonably well treated by the Japs while in the concentration camp. The usual lack of maintenance was evident but its results were less noticeable than in the cities to the south.

Peking. The writer visited Peking while traveling from Tientsin to Shanghai but was unable to learn much about the existing water supply. It would be expected that the same artesian supply available at Tientsin would be available at Peking. It is reported that the earlier supplies for the city were from shallow wells and doubtless a large proportion of the native population depends upon the ponds and rivers for water.

The city itself was scarcely touched by the war and is a most fascinating city to visit.

Shanghai. The Shanghai waterworks came under the Army and its inspection was not part of the writer's mission. However, he visited the treatment plant of the British Concession as a matter of personal interest. The British waterworks is the largest and most modern in the former International Settlement. At present the Chinese control the government of Shanghai and are trying to jockey the British out of control of the water works and other utilities. The present charge for water is limited to $10 per mil gal, which, at the usual 70-mgd rate of supply, amounts to only $700 per day to run the system, which supplies well over a million people.

The water treatment plant is a combined rapid and slow sand filtration plant. The raw water is from the Whangpoo River below Shanghai and this water is generally considered to be one of the most highly polluted waters in the world. During certain times in the year bacterial counts of 6,000,000 per cc have been observed. The river receives all the drainage of the city plus the wastes from the tremen-

dous shipping in the river. The river drains an extensive area of farmland on which the principal fertilizer is human excrement.

The raw water is dosed with alum, flows through a baffled mixing chamber and thence to a sedimentation chamber, where it is held about 16 hours. A portion of the water goes to slow sand filters and the remainder to rapid sand filters. The filters are similar to standard American design and dimensions. The filtered water is stored in large covered basins and then pumped to the city by steam-engine-driven pumps. Since there is no elevated storage in the city, pumping has to be continuous to maintain pressure, similar to the Holly system used in the past by a number of American cities. Before the war chlorine was added before filtration (rapid sand filters only), after filtration, and at the suction of the high-lift pumps. There are duplicate electric-motor-driven and Diesel-engine-driven pumps throughout most of the plant, to take advantage of variations in the relative price of electricity and Diesel oil.

The British reported that the first Japanese who took over the operation of the plant were quite competent, being from the Tokio waterworks. After a short time they were replaced by less competent men, who were, in turn, replaced by even less competent men, until finally the men in charge of the plant were more interested in padding their expense accounts than in operating the plant. The Chinese became accomplished in sabotage, of which loafing formed a major part, and now they appear unable to get over the habit.

Chemicals are very hard to get. A natural alum, containing 24 molecules of water of crystallization and having an equivalent of 10% of alumina (Al_2O_3), was being used. This material could not be fed with ordinary chemical feeders, because it caked badly. A temporary solution feeder, using a water spray and an oil barrel, was devised to feed the alum. Liquid chlorine was not available, so bleaching powder was being used. The powder was first mixed with a small amount of water in a concrete mixer, containing a few shovelfuls of gravel stone to break up the lumps, and then diluted in a large concrete tank. The chlorine solution was being fed by gravity and only to the suction of the high-lift pumps, because of the difficulty of maintaining an adequate supply of chlorine. When visited, the plant had only a three-day supply of alum and bleaching powder on hand

and reported having been down to a 20-minute supply on several occasions.

The Japs had neglected maintenance as usual and the mixing tanks had 10-foot deposits of mud in places. The filter sand was more mud than sand.

The purity of the water was being maintained but, due to lack of capacity, it was necessary to cut the pumping pressures, thus presenting the danger of pollution entering the mains at times of negative pressures. At the time of the writer's visit the situation at Shanghai was certainly most precarious.

The preceding notes serve to illustrate the hazardous condition of typical waterworks in some of the larger coastal cities of China. Obviously, much reconstruction work lies ahead for those entrusted with the water systems of ravished China.

HYDRANT-FLOW AND PIPE-CONDITION TESTS

BY SCOTT KEITH*

[*Received December 6, 1945.*]

IN the study of any existing water-distribution system, two types of field tests are essential to furnish data for use in network analysis—hydrant-flow tests and pipe-condition tests.

Hydrant-flow tests will provide direct evidence of local as well as general hydraulic deficiency in the system.

Pipe-condition tests are necessary to furnish information for basis of selection of the proper resistance coefficient, where the use of judgment alone in the selection of the coefficient may result in misleading conclusions in any network analysis. This is particularly true in systems consisting of unlined cast-iron pipe of different ages and carrying a corrosive water, where a wide range of coefficients may occur and where not infrequently the carrying capacity of some part of the system may be found to be as low as one-third of the original carrying capacity of the pipe.

Either of these tests can be made satisfactorily with the hydrant pitot, provided certain precautions are taken.

Hydrant-Flow Tests. The procedure in hydrant-flow tests in large distribution systems is described by Gordon M. Fair (1) and by George W. Booth (2). In smaller systems, hydrant-flow tests from a series of single hydrants may be sufficient, in which case the pressure before and during the flow may be taken with a Bourdon pressure gage, mounted on one hose outlet of any hydrant, and the quantity of flow may be measured by hydrant pitot at another hose outlet of the same hydrant.

The pressures should be taken with a test gage, previously calibrated, and preferably with at least a 5-in. diameter dial. Pressures under "static" (hydrant closed) and dynamic (hydrant flowing) conditions should be recorded to the nearest one-half pound.

The inside diameter of the hydrant outlet opened for discharge

*With Metcalf & Eddy, Statler Bldg., Boston, Mass.

should be carefully measured by means of inside calipers and recorded to the nearest 1/64 inch.

The rate of flow from the hydrant can be measured by the hydrant pitot, consisting of a suitably streamlined pitot tube connected to a 3-in. test gage, on which the velocity head of the discharge at the hydrant outlet is indicated. The pitot should be centered in the discharging stream. The pressure indicated on the hydrant pitot should be recorded to the nearest one-half pound. Fig. 1 illustrates one type of hydrant pitot.

For a well-shaped and smooth hydrant outlet the coefficient to be applied to the indicated velocity to obtain the average velocity over

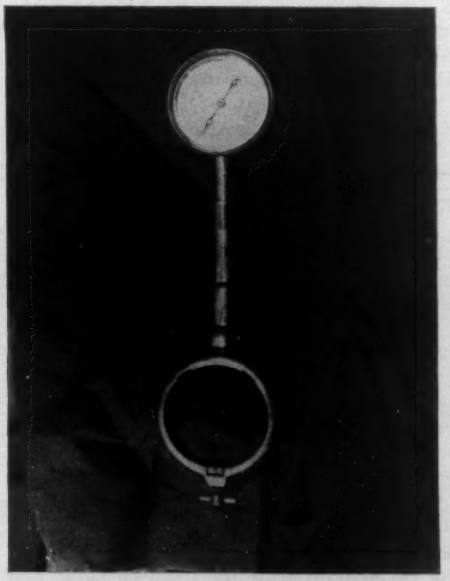


FIG. 1.—HYDRANT PITOT.

the cross-section is generally taken as 0.90, from which the following formula for the rate of discharge from the hydrant may be derived:

$Q = 26.85\ D^2\ h^{1/2}$, where

Q = discharge, in gallons per minute;

D = inside diameter of the hydrant outlet, in inches;

h = indicated pressure on the hydrant pitot, in pounds per square inch.

For convenience, a tabulation of discharge for various diameters of outlets and hydrant-pitot pressures is given in Appendix A.

It should be noted that any error in measurement of the internal diameter of hydrant orifice, expressed as a percentage, results in twice this percentage of error in the computed discharge rate from the hydrant. For example, if the outlet diameter is taken as 2½ in. and the hydrant-pitot reading is 30 lb per sq in., the discharge from the hydrant is 920 gpm. If the error in measuring the orifice is 1/16 inch, or 2.5% variation, the error in discharge rate may be computed as follows:

$$\Delta = \frac{d}{dD}\ (26.85\ D^2\ h^{1/2})$$

$\Delta = 26.85 \times 2D\ h^{1/2}\ \delta$, where $\delta = 1/16$

$\Delta = 26.85 \times 2 \times 2.5 \times 5.47 \times 1/16$

$\Delta = 46$ gpm, or 5.0%.

Under the same assumptions, an error in reading the pressure gage of the hydrant pitot of ½ lb, or 1.67%, will result in the following error in discharge rate:

$$\Delta = \frac{d}{dh}\ (26.85\ D^2\ h^{1/2})$$

$$\Delta = 26.85 \times \frac{D^2}{2\ h^{1/2}} \times ½, \text{ where } h = 30 \text{ and } D = 2½$$

$$\Delta = \frac{26.85 \times 6.25}{2 \times 5.47 \times 2}$$

$\Delta = 7.7$ gpm, or 0.84%, or half of the percentage of error in gage pressure.

For rough work, reasonably accurate results can be obtained without using the hydrant pitot, as it will be found that the residual pressure (with the hydrant flowing) indicated by the pressure gage

at the hydrant is generally within one or two pounds of that indicated by the hydrant pitot; therefore, the discharge may be computed by using the pressure from the gage at the closed outlet in the above formula.

A check on the static pressure of the hydrant may be obtained by noting the elevation of the hydrant-pressure gage by means of a surveying aneroid barometer.

A suggested form for the recording of the field data to be obtained is given in Appendix B.

Pipe-Condition Tests. The pipe-condition test involves the measurement of the loss of head between two selected points of known distance apart on the pipe line at a measured rate of flow. Once the loss of head per unit of length for a given discharge is determined, the resistance coefficient may be computed from any chosen discharge formula. A schematic diagram of the data involved is given in Fig. 2.

In Fig. 2 let Q_1 = rate of flow for domestic or other consumption, prior to opening the hydrant;

Q_2 = induced flow at the hydrant at, or near, point b;

P_{a1} = pressure at point a with flow of Q_1;

P_{a2} = pressure at point a with flow of $Q_1 + Q_2$;

P_{b1} and P_{b2} = pressures at point b at flows of Q_1 and $Q_1 + Q_2$, respectively;

Z_a = elevation of center line of gage at point a;

Z_b = elevation of center line of gage at point b.

The slope of the hydraulic gradient between points a and b, at the discharge Q_1, is then represented by:

$$S_1 = \frac{(Z_a + P_{a1}) - (Z_b + P_{b1})}{L}$$

Similarly, the slope of the hydraulic gradient between points a and b at a discharge of $Q_1 + Q_2$ is:

$$S_2 = \frac{(Z_a + P_{a2}) - (Z_b + P_{b2})}{L}$$

If the Hazen-Williams formula is used:

$Q = 1.318\, ACR^{0.63}\, S^{0.54}$, where

Q = discharge, in cubic feet per second;

A = cross-sectional area of the pipe, in square feet;

C = resistance coefficient;

R = hydraulic radius of the pipe, in feet;

S = slope of the hydraulic gradient (expressed as a decimal).

Then, under conditions of flow existing prior to opening the hydrant:

$$Q_1 = 1.318\,ACR^{0.63}\,S_1^{0.54} \qquad (1)$$

and under conditions of flow existing with the hydrant open:

$$Q_1 + Q_2 = 1.318\,ACR^{0.63}\,S_2^{0.54} \qquad (2)$$

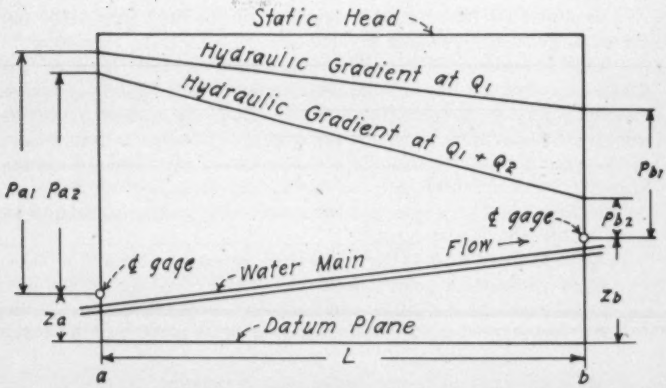


FIG. 2 —Schematic Diagram of Flow Conditions during Pipe Condition Test.

Combining equations (1) and (2):

$$Q_2 = 1.318\,ACR^{0.63}\,(S_2^{0.54} - S_1^{0.54}), \text{ or}$$

$$C = \frac{Q_2}{1.318\,AR^{0.63}\,(S_2^{0.54} - S_1^{0.54})} \qquad (3)$$

Hence it is seen that the resistance coefficient *"C"* may be determined directly, without measurement of the rate of domestic flow in the pipe, but by measurement of the induced draft at the hydrant and of the slopes of the hydraulic gradient S_1 and S_2, only.

This method, involving the use of equation (3), obviates the making of condition tests during the night-time, when domestic and industrial consumption are reduced to a minimum. Any error involved

will be that due to a change in the domestic or industrial consumption during the short period of a few minutes between the time pressure readings are taken before the hydrant is opened and the readings when the hydrant is fully opened.

In equation (3) the term $1.318\ AR^{0.63}$ in the denominator is a constant for any given size of pipe. Values of this expression are tabulated in Appendix C for pipe sizes from 4-inch to 48-inch. A plot on logarithmic paper for the solution of values of $S^{0.54}$ is given in Appendix D, or these values may be determined from a log-log slide rule.

The determination of the resistance coefficient *"C"* is thus found to resolve into:

(a) Measurement of the rate of induced draft, created by flow from a hydrant in the vicinity of point *b*, by means of the hydrant pitot, and

(b) Measurement of the slope of the hydraulic gradient between points *a* and *b*, both before and during the opening of the hydrant near point *b*. The determination of slopes obviously involves measuring the length *"L"*, the elevations of the center lines of the pressure gages at points *a* and *b*, and the pressures indicated at these gages.

For those desiring to use the Chezy formula, instead of the Hazen-Williams formula, for the determination of the resistance coefficient, equation (3) becomes:

$$C = \frac{Q_2}{A\sqrt{R}\,(\sqrt{S_2} - \sqrt{S_1})} \qquad (3A)$$

from which Fanning's f may be derived from the relation $f = \frac{8g}{C^2}$.

Sites for flow-condition tests should be selected so as to provide:

(a) Representative tests on pipes of various known ages;

(b) Sufficient length such that the loss of head will be of readily measured magnitude, preferably at least 1,000 ft.;

(c) Test length free from branch pipes or drafts from the main being tested (If branch pipes do occur within the test length, the valves on the branches should be closed.);

(d) Division gates should be closed so that the flow to the hy-

drant, where draft is being induced, will be in one direction only.

Test Procedure. The condition test requires at least two observers, one to record the upstream pressure-gage readings, and one to record the downstream pressure-gage readings and the flow at the hydrant as determined from the hydrant pitot. In case the downstream pressure gage is not installed on the same hydrant as that opened but is installed on some adjacent sillcock, a third observer will be required.

Each observer should be equipped with a watch provided with a second-hand and all watches should be synchronized.

One observer should be left at the upstream pressure gage and a time should be agreed upon for opening the downstream hydrant. It is advisable for the upstream pressure observer to record the pressures every 15 sec for several minutes before the set time for opening the hydrant, and readings should be continued until the pressure has reached a minimum, has become stabilized during the period of hydrant discharge and has again returned to static conditions (as represented by pressures with the hydrant closed). The downstream pressure observer should follow a similar procedure. The hydrant should remain open for sufficient time to permit flow conditions to become stabilized, probably a matter of 3 to 5 min.

The pressure gages should be test gages, calibrated both before and after the series of tests, and preferably with a dial at least 5 in. in diameter. Readings should be taken to the nearest ½ lb, or to the nearest division on the gage dial.

Elevations of the center line of pressure gages should be taken by instrument leveling.

The hydrant pitot should be of the same type previously described for hydrant-flow tests and the pitot readings should be recorded to the nearest ½ or ¼ lb. The diameter of the hydrant outlet should be measured with inside calipers to the nearest 1/64 inch.

The distance between the pressure gages, representing the length of pipe being tested, should be measured along the pipe, either by stadia or by steel tape. The measurement of length, as explained later, does not require the precision that the other test observations require. It is often convenient, however, to measure the length with a 100-ft

drag steel tape, marking off each tape length with a marking crayon on the street paving.

A suggested form for recording the field notes is given in Appendix E.

Precision of Measurement. The variations in the resistance coefficient "*C*" in the Hazen-Williams discharge formula for a given error in measurement of the length "*L*" or the head "*h*" may be determined as follows.

Assume that the condition test indicates no drop in the hydraulic gradient under "static" conditions (*i.e.* $S_1 = 0$); that the drop in gradient "*h*" with a flow of 1,000 gpm, or 2.23 cfs, is found to be 5.0 ft within a measured length of 1,000 ft. The pipe diameter is 12-inch. $S_2 = 0.005$. From the Hazen-Williams equation,

$$C = \frac{Q}{KS^{0.54}},$$

where $K = 0.4322$ (see Appendix C), or

$$C = \frac{2.23}{0.4322 \times 0.057} = 90.5.$$

If the length "*L*" of 1,000 ft has been measured with an error of 5 ft, or 0.5%,

$$C = \frac{QL^{0.54}}{Kh^{0.54}}, \text{ from which}$$

$$\Delta = \frac{d}{dL}\frac{(QL^{0.54})}{(Kh^{0.54})} = \frac{Q \times 0.54\hat{\delta}}{Kh^{0.54}L^{0.46}} = \frac{2.23 \times 0.54 \times 5}{0.432 \times 2.38 \times 24}$$

$\Delta = 0.245$ or 0.27%, which error is negligible.

On the same basis, assuming the head "*h*" is measured with an error of 0.5 ft (or about ¼ lb per sq in. error in gage reading) in 5.0 ft, or 10%:

$$\Delta = \frac{d}{dh}\frac{(QL^{0.54})}{(Kh^{0.54})} = \frac{QL^{0.54} \times 0.54\hat{\delta}}{Kh^{1.54}}$$

where $\hat{\delta} = 0.5$

$$\Delta = \frac{2.23 \times 42 \times 0.54 \times 0.5}{0.432 \times 11.9} = 4.92, \text{ or } 5.5\%.$$

It is, therefore, apparent that any measurement made in relation to

head should be made as accurately as practicable. Measurement of length *"L"* may be made with quite ordinary precision without appreciable effect upon the determination of the resistance coefficient.

Office Computations for the hydrant-flow test consist merely of applying the corrections to the pressure-gage readings and the recorded pressure reading of the hydrant-pitot gage, obtained from the calibration curves of the particular gages, computing the hydrant discharge and adjusting this discharge to a residual pressure of 20 lb per sq in. This adjustment may be made directly on the Hazen-Williams hydraulic slide rule, or by means of the relation Q varies as $h^{0.54}$ and the use of the log-log slide rule.

Sample computations for both the hydrant-flow and pipe-condition tests are given in Appendix F.

References

(1) Fair, Gordon M. "Hydraulic Investigation of Water Distribution Systems in Field and Office," This Journal, 55, 281 (1941).

(2) Booth, George W. "Methods of Making Flow Tests and Their Value to Water Works Engineers," Journal A.W.W.A., 12, 157 (1924). See also Jour. A.W.W.A., 19, 542 (1928).

DISCHARGE THROUGH HYDRANT OUTLETS

(11-27-45)

METCALF & EDDY
ENGINEERS
BOSTON, MASS.
NOV. 1945

$Q = 26.85 d^2\sqrt{h}$

d = OUTLET DIAMETER, INCHES
h = PRESSURE, POUNDS PER SQUARE INCH

GALLONS PER MINUTE

PRESSURE LBS./0"	INTERNAL DIAM HYDRANT OUTLET, INCHES						
	2 3/32	2 1/16	2 5/32	2 1/2	2 7/32	2 9/16	2 19/32
1/2	110	115	115	120	120	125	130
1	155	160	165	170	170	175	180
1 1/2	190	195	200	205	210	215	220
2	220	225	230	235	245	250	255
2 1/2	245	250	260	265	270	280	285
3	270	275	285	290	300	305	315
3 1/2	290	300	305	315	320	330	340
4	310	320	325	335	345	350	360
4 1/2	330	340	345	355	365	375	385
5	350	355	365	375	385	395	405
5 1/2	365	375	380	395	405	415	425
6	380	390	400	410	420	430	445
6 1/2	395	405	415	425	440	450	460
7	410	420	430	445	455	465	480
7 1/2	425	435	450	460	470	485	495
8	440	450	465	475	485	500	510
8 1/2	455	465	475	490	500	515	525
9	465	480	490	505	515	530	540
9 1/2	480	490	505	515	530	545	555
10	490	505	520	530	545	555	570
10 1/2	505	515	530	545	560	570	585
11	515	530	545	555	570	585	600
11 1/2	525	540	555	570	585	600	615
12	540	550	565	580	595	610	625
12 1/2	550	565	580	595	610	625	640
13	560	575	590	605	620	635	650
13 1/2	570	585	600	615	630	650	665
14	580	595	610	630	645	660	675
14 1/2	590	605	625	640	655	670	690
15	600	615	635	650	665	685	700
16	620	640	655	670	690	705	725
17	640	655	675	690	710	725	745
18	660	675	695	710	730	750	765

PRESSURE LBS./0"	INTERNAL DIAM HYDRANT OUTLET, INCHES						
	2 3/32	2 1/16	2 5/32	2 1/2	2 7/32	2 9/16	2 19/32
19	675	695	715	730	750	770	790
20	695	715	730	750	770	790	810
21	710	730	750	770	790	810	830
22	730	750	765	785	805	825	845
23	745	765	785	805	825	845	865
24	760	780	800	820	845	865	885
25	775	795	820	840	860	880	905
26	790	815	835	855	875	900	920
27	805	830	850	870	895	915	940
28	820	845	865	890	910	935	955
29	835	860	880	905	925	950	975
30	850	875	895	920	940	965	990
31	865	890	910	935	960	980	1005
32	880	900	925	950	975	995	1020
33	895	915	940	965	990	1015	1040
34	905	930	955	980	1005	1030	1055
35	920	945	970	995	1020	1045	1070
36	930	955	980	1005	1030	1060	1085
37	945	970	995	1020	1045	1070	1100
38	960	985	1010	1035	1060	1085	1115
39	970	995	1020	1050	1075	1100	1130
40	985	1010	1035	1060	1090	1115	1140
41	995	1020	1050	1075	1100	1130	1155
42	1005	1035	1060	1090	1115	1145	1170
43	1020	1045	1075	1100	1130	1155	1185
44	1030	1060	1085	1115	1140	1170	1200
45	1040	1070	1100	1125	1155	1185	1210
46	1055	1080	1110	1140	1165	1195	1225
47	1065	1095	1120	1150	1180	1210	1240
48	1075	1105	1135	1165	1190	1220	1250
49	1090	1115	1145	1175	1205	1235	1265
50	1100	1130	1155	1185	1215	1245	1275

KEITH

APPENDIX B
FIELD DATA SHEET FOR HYDRANT-FLOW TEST

Hydrant Flow Test

Location Plymouth, Mass.

Street Stephens St. at Sandwich St.

Date Oct. 4, 1945 Time 10:50 A. M.

Hydrant No. 215 ; Diam. Outlet 2 7/16"

Top of Hydrant, Elevation 34.8

Top of Hydrant (above) ~~(below)~~
Center of Gage 1.1 ft.

Pressure Gage Number Fox. # 2
Pressure, lb./sq. in.
Static (Hydrant Closed) 59 *

Residual (Hydrant Open) 45 *

Hydrant Pitot Gage No. 860 441

Pitot Pressure, lb./sq.in. 43 *
Approximate Hydrant Discharge,

1045 g.p.m.*
Approximate Drop in Pressure,

14 * lb./sq. in.
Approximate Hydrant Discharge at
Residual Pressure of 20 lb./sq.in

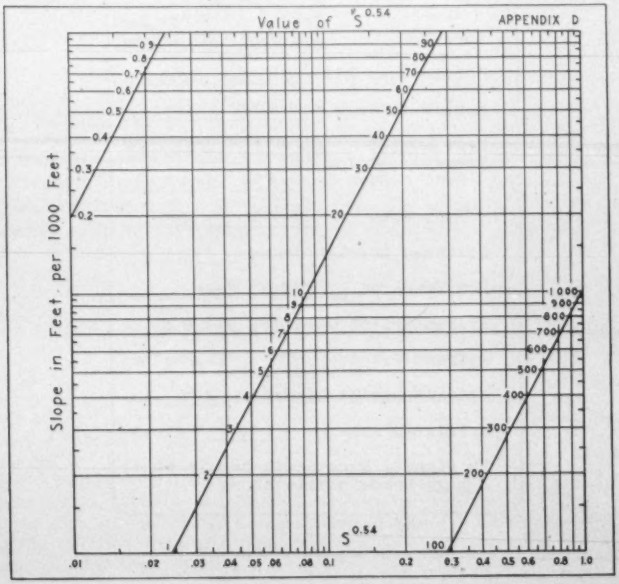
1820 * g.p.m.

*Subject to gage correction.

APPENDIX C

VALUES OF THE EXPRESSION 1.318 $AR^{0.63}$ FOR VARIOUS SIZES OF PIPES

Pipe diameter (inches)	Value of 1.318 $AR^{0.63}$	Pipe diameter (inches)	Value of 1.318 $AR^{0.63}$
4	0.02404	18	1.255
6	0.06972	20	1.657
8	0.1488	24	2.676
10	0.2669	30	4.812
12	0.4322	36	7.773
14	0.6485	42	11.66
16	0.9208	48	16.57



APPENDIX E
FIELD DATA SHEET FOR PIPE-CONDITION TEST

Pipe Condition Test

Location Whitman, Mass.

Street Bedford St. - Regulator to Auburn

Date Oct. 23, 1944 Time _____ M.

Size of Pipe 16" Year Laid 1905

Type of Lining None

Location	Hydrant Feed End Hyd. #120	Hydrant Flow End Silcock #300
Nozzle C.L. El.	87.00	103.80
Nozzle to Gage *	+1.00	—
Gage Number	Fox. # 1	504 044
Pressure, lb./sq.in. Hyd. Closed	78¼	70
Hyd. Open	64½	52

Distance Between Gages 1927'

How Measured Steel Tape

Hydrant Pitot Gage No. Fox. # 2

Hydrant Pitot 47 lb./sq.in.

Hydrant Outlet Diameter 2½ in.

Hydrant Discharge 1150 g.p.m.

*Designate gage above nozzle as +; gage below nozzle as -.

APPENDIX F
Hydrant-Flow Test

Location: Plymouth, Mass.		
Test No.: 40		
Street: Stephens St. at Sandwich St.		
Hydrant No.: 215		
Date: Oct. 4, 1945		
Elevation of Top of Hydrant	34.8	
Distance Top of Hydrant to Center of Gage	—1.1	
Elevation of Center of Gage	33.7	
Static Conditions (Hydrant Closed), Gage Number Foxboro #2		
Gage Reading, lb./sq. in.	59	
Corrected Gage Reading, lb./sq. in.		59
Residual Pressure (Hydrant Open)		
Gage Reading, lb./sq. in.	45	
Corrected Gage Reading, lb./sq. in.		45
Drop in Pressure, lb./sq. in.		14
Hydrant Pitot, Gage Number 860,441		
Pitot Gage Reading, lb./sq. in.	43	
Corrected Gage Reading, lb./sq. in.	44.0	
Diameter of Orifice, inches	2 7/16	
Hydrant Discharge, g.p.m.	1,060	
Hydrant Discharge at 20 lb./sq. in. Residual Pressure, 1,840 g.p.m.		
Reservoir or Storage Level, Elev.	167.0	
Center of Gage, Elev.	33.7	
	133.3 feet	
Equivalent Static Pressure, lb./sq. in.	57.8	

APPENDIX F
Pipe-Condition Test

Location: Whitman, Mass.
Test No. 12
Street: Bedford Street from Regulator to Auburn Street
Date: Oct. 23, 1944
Size of Pipe: 16 inch. Kind: Cast iron. Lining: None.
Length: 1,927 feet. How determined: Steel tape.
Year laid: 1905. Age: 39 years.

Location	Hydrant Number	Observer	Pressure Gage No.
Feed End	120	S.K.	Foxboro #1
Flow End	Sillcock opp. #300 Bedford		504,044
Hydrant Pitot	Hyd. south of Auburn St.	C.E.C.	Foxboro #2

	Feed End		Flow End	
	lb./sq. in.	Feet	lb./sq. in.	Feet
Pressure Gage Elevation				
Center Line of Nozzle	—	87.00	—	103.80
Distance to Center Line Gage	—	1.00	—	——
Elevation Center Line Gage		88.00		103.80
Hydrant Closed (Q_1)				
Gage Reading	78¼	——	70	——
Corrected Gage Reading	78.5	181.15	72.8	161.54
Elev. of Hydraulic Gradient		269.15		265.34
Difference (Feed End Minus Flow End)			3.81 feet = h_1	
Slope of Gradient, $h_1/L = S_1 = \frac{3.81}{1927} = 0.00198$; $S_1^{0.54} = 0.034$				
Hydrant Open ($Q_1 + Q_2$)				
Gage Reading	64½	——	52	——
Corrected Gage Reading	64.5	148.85	54.5	120.00
Elevation Center Line Gage		88.00		103.80
Elevation of Hydraulic Gradient		236.85		223.80
Difference (Feed End Minus Flow End)			13.05 feet = h_2	
Slope of Gradient, $h_2/L = S_2 = \frac{13.05}{1927} = 0.00677$; $S_2^{0.54} = 0.067$				

Induced Flow (Q_2)

Pitot Gage Reading	47
Corrected Gage Reading	47.0
Diameter of Orifice	2½ inches
Discharge, Q_2	1150 gpm = 2.56 cfs

Determination of Hazen-Williams "C"

Value of $K = 1.318\ AR^{0.63} = 0.9208$

$$C = \frac{Q_2}{K(S_2^{0.54} - S_1^{0.54})} = \frac{2.56}{0.9208(0.067 - 0.034)}$$

$$C = \frac{2.56}{0.9208 \times 0.033} = 84$$

UNITED STATES PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS

1946 EDITION*

Federal Security Agency
United States Public Health Service
Washington, D. C., Feb. 6, 1946

The standards included herein have been promulgated as Regulations of the United States Public Health Service and published in the Federal Register. These standards supersede the standards adopted on September 25, 1942, and recommended by the Advisory Committee on the Revision of the 1925 Drinking Water Standards. They are recommended and approved by the same Advisory Committee.

Effective upon their date of publication in the Federal Register, these regulations represent standards to which drinking water and water supply systems used by carriers and others subject to Federal Quarantine regulations must conform. These standards are in a form believed suitable for use generally in evaluating quality and safety of water and water supply systems.

THOMAS PARRAN
Surgeon General
United States Public Health Service

sgd. MAURICE COLLINS
Acting Administrator
Federal Security Agency

PREFACE TO THE 1942 EDITION[1]

The following preface to the 1942 edition of the Public Health Service Drinking Water Standards is included, partly from the standpoint of historical interest, but primarily because the basic ideas expressed in the statement of the Advisory Committee included therein are still valid.

*Published in Public Health Reports, March 15, 1946.
[1]See This Journal, 58:2, 112, June, 1944.

Report of the Advisory Committee on Official Water Standards

The requirements for drinking (and culinary) water provided by common carriers for the use of passengers carried in interstate traffic, commonly known as the "Treasury Department Drinking Water Standards," were last revised in 1925 and published in the Public Health Reports of April 10 of that year. Since that time many improvements in water supply practice have been adopted with resulting increased uniformity of quality and safety to the consumer. Moreover, the Public Health Service, in recent years, has been requested by the American Public Health Association, the American Water Works Association, and the American Chemical Society to review the 1925 Standards. Accordingly, the Public Health Service has undertaken a revision of the Standards in order to have them conform more closely to current requirements for water supplies of attainable safety and potability.

To carry out such a revision the Surgeon General of the Public Health Service, on February 27, 1941, appointed the undersigned special Advisory Committee composed of representatives of various Federal organizations and scientific associations and including several members at large. A smaller subcommittee of Public Health Service officers was designated to prepare tentative suggestions for the consideration of the Advisory Committee.

After thorough consideration, the Advisory Committee recommends the adoption of the revisions as set forth in the text herewith submitted. The principal changes now proposed are:

(1) A distinct separation of the text into: (a) that portion containing the statement of the Standards, and (b) that portion constituting a recommended manual of water works practice representing the judgment of the technical subcommittee composed of officers of the Public Health Service. This portion of the text is intended to serve as a guide to the reporting agency and should not be considered as indicating additional requirements to be met for certification of the water supply.

(2) In the bacteriological section the use of 5-10 ml. portions or of 5-100 ml. portions is made optional; a minimum number of samples is to be examined monthly, the number depending upon the

population served; the laboratories in which bacteriological examinations are made and the methods used in making them are subject to inspection at any time by the designated representative of the certifying authority.

(3) Concentration limits for lead, fluoride, arsenic, and selenium are included as part of the Standards and their presence in excess of the limits stated shall constitute ground for rejection of the supply. Limits in concentration that should not be exceeded, where other more suitable supplies are available, are given for copper, iron and manganese together, magnesium, zinc, chloride, sulfate, phenolic compounds, total solids, and alkalinity.

(4) The results of recent studies on the potential pollutional hazards existing in the water supply systems of our communities due to faulty plumbing practices, cross-connections, interconnections, etc., as well as the pollutional hazards which are due to faulty water plant and distribution system operational practices, any or all of which may jeopardize the safety of the water in the distribution system, have been adjudged as being of prime importance in the consideration of the requirements of these Standards. The utmost care and consideration have been given to the inclusion of those provisions which would serve to detect possible contamination arising in the distribution system and thus lead to its correction and further safeguarding of the traveling public.

The Committee believes that, in general, water supplies to be eligible for certification should meet all (sanitary, chemical, and bacteriological) requirements of the Standards and that definite failure to meet any one of them should be ground for rejection or provisional certification, according to the judgment of the certifying authority. However, it is realized that the statement of an official standard of drinking water quality, to be generally applicable, must be interpreted reasonably. The Committee has attempted to take into consideration all aspects of the problem. It offers these Standards with the recommendation that the judgment and discretion of the certifying authority be exercised in their application.

Public Health Service Drinking Water Standards, 1946

Standards Promulgated by the United States Public Health Service, Federal Security Agency, February 5, 1946, for Drinking and Culinary Water Supplied by Carriers Subject to the Federal Quarantine Regulations.

(Superseding Standards Adopted September 25, 1942)

Report of the Advisory Committee on Official Water Standards

Experience gained by the Certifying Authority during three years' utilization of the Standards adopted in 1942 indicates a need for revision of wording and clarification of certain sections of these Standards. During the period these Standards were in effect it became necessary to issue State Health Officers' Circular Letter No. 85 in order that the Standards would be properly and uniformly applied. It is believed desirable to have the Standards worded in such a manner that they are suitable for utilization without further clarification.

Heretofore drinking water standards adopted by the Public Health Service have been designed to apply specifically to those water supplies used by carriers subject to the Interstate Quarantine Regulations. The present revision contemplates a standard for water quality generally acceptable and applicable to all public water supplies in the United States.

It has been with these two objectives in mind that this revision of the Standards has been effected. No major changes have been made in the basic requirements of the Standards, but certain requirements have been restated in such a manner as to make them more readily applicable to existing water supplies. In writing these Standards in a manner that will allow their application to all public water supplies, no inference is meant or desired that the authority of the Public Health Service should be extended to include any water supplies other than those used by carriers subject to the Federal Quarantine Regulations.

It will be noted that the Manual of Recommended Water Sanitation Practice referred to in the Preface to the 1942 edition of the Standards has not been included in this edition. While this manual was intended merely as an advisory guide, in practice it was found

that it, at times, was being used as a part of the Standards and for this reason is omitted from the present text.

MEMBERSHIP OF ADVISORY COMMITTEE ON REVISION OF THE DRINKING WATER STANDARDS[1]

Joseph W. Mountin, *Chairman, Assistant Surgeon General, States Relations Division, U. S. Public Health Service, Washington, D. C.*

J. K. Hoskins, *Secretary, Senior Sanitary Engineer, Chief, Sanitation Section, U. S. Public Health Service, Washington, D. C.*

REPRESENTATIVES OF FEDERAL ORGANIZATIONS

Food and Drug Administration: J. W. Sale, Senior Chemist, Food Division, Federal Security Agency, Washington, D. C.

U. S. Geological Survey: W. D. Collins, Chemist in Charge, Quality of Water Division, Department of the Interior, Washington, D. C.

REPRESENTATIVES OF SCIENTIFIC ASSOCIATIONS

American Chemical Society: A. M. Buswell, Chief, Illinois State Water Survey Division, Urbana, Ill.

American Public Health Association: Abel Wolman, Professor of Sanitary Engineering, Johns Hopkins University, Baltimore, Md.

American Society of Civil Engineers: Arthur E. Gorman, Engineer of Water Purification, Bureau of Engineering, Department of Public Works, Chicago, Ill.

American Water Works Association: Charles R. Cox, Chief, Bureau of Water Supply, State Department of Health, Albany, N. Y.

Association of American Railroads: R. C. Bardwell, Superintendent, Water Supply, Chesapeake and Ohio Railroad, Richmond, Va.

Conference of State Sanitary Engineers: Arthur D. Weston, Director and Chief Engineer, Division of Sanitary Engineering, State Department of Public Health, Boston, Mass.

Society of American Bacteriologists: A. C. Hunter, Principal Bacteriologist, Food and Drug Administration, Federal Security Agency, Washington, D. C.

MEMBERS AT LARGE

Herman G. Baity, Professor of Sanitary Engineering, University of North Carolina, Chapel Hill, N. C.

R. E. Buchanan, Director, Agricultural Experiment Station, Iowa State College, Ames, Iowa.

R. F. Goudey, Sanitary Engineer, Bureau of Water Works and Supply, Los Angeles, Cal.

[1]Official positions indicated are as of February 27, 1941, when the Committee was organized.

Technical Subcommittee, Officers of the Public Health Service

J. K. Hoskins, Senior Sanitary Engineer, Chief, Sanitation Section, States Relations Division, Washington, D. C. (Secretary).

R. E. Tarbett, Senior Sanitary Engineer, Washington, D. C.

H. W. Streeter, Senior Sanitary Engineer, Stream Pollution Investigations, Cincinnati, Ohio.

C. T. Butterfield, Principal Bacteriologist, Stream Pollution Investigations, Cincinnati, Ohio.

C. C. Ruchhoft, Principal Chemist, Stream Pollution Investigations, Cincinnati, Ohio.

Lawrence T. Fairhall, Principal Industrial Toxicologist, National Institute of Health, Bethesda, Md.

1. Definition of Terms*

For the purpose of these Standards the terms designated herein below shall be defined as follows:

1.1. *Adequate protection by natural agencies* implies various relative degrees of protection against the effects of pollution in surface waters: dilution, storage, sedimentation, the effects of sunlight and aeration, and the associated physical and biological processes which tend to produce natural purification; and, in the case of ground waters, storage in and percolation through the water bearing material.

1.2. *Artificial treatment* includes the various processes commonly used in water treatment, both separately and in combination, such as storage, aeration, sedimentation, coagulation, rapid or slow sand filtration, chlorination, and other accepted forms of disinfection. Rapid sand filtration treatment is commonly understood to include those auxiliary measures, notably coagulation and sedimentation, which are essential to its proper operation.

1.3. *Adequate protection by artificial treatment* implies that the method and degree of elaboration of treatment are appropriate to the source of supply; that the works are of adequate capacity to support maximum demands, are well located, designed, and constructed, are carefully and skillfully operated and supervised by properly trained and qualified personnel, and are adequately protected against floods and other sources of pollution. The evidence that the protection thus afforded is adequate must be furnished by frequent bacteriological examinations and other appropriate analyses showing that the

*The section numbering employed throughout this text differs from that used in the Federal Register, but maintains a parallel with the numbering of the 1942 Standards with which those in the water works field are familiar.

purified water is of good and reasonably uniform quality, a recognized principle being that irregularity in quality is an indication of potential danger. A minimum specification of good quality would be conformance to the bacteriological and chemical requirements of these Standards, as indicated in sections 3 and 4.

1.4. *Sanitary defect* means any faulty structural condition, whether of location, design, or construction of collection, treatment, or distribution works which may regularly or occasionally prevent satisfactory purification of the water supply or cause it to be contaminated from extraneous sources. Among the extraneous sources of contamination of water supply are dual supplies, by-passes, cross-connections, interconnections, and back-flow connections.

1.5. *Health hazard* means any faulty operating condition including any device or water treatment practice, which, when introduced into the water supply system, creates or may create a danger to the well-being of the consumer.

1.6. *Water supply system* includes the works and auxiliaries for collection, treatment, and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer.

1.7. *The coliform group of bacteria* is defined, for the purpose of these Standards, as including all organisms considered in the coli-aerogenes group as set forth in the Standard Methods for the Examination of Water and Sewage, current edition, prepared, approved, and published jointly by the American Public Health Association and the American Water Works Association, New York City. The procedures[1] for the demonstration of bacteria of this group shall be those specified herein, for:

(a) The completed test, or

(b) The confirmed test when the liquid confirmatory medium brilliant green bile lactose broth, 2 per cent, is used, providing the formation of gas in any amount in this medium during 48 hours of incubation at 37° C. is considered to constitute a positive confirmed test, or

(c) The confirmed test when one of the following liquid confirmatory media is used: crystal violet lactose broth, fuchsin lactose

[1]This reference shall apply to all details of technique in the bacteriological examination, including the selection and preparation of apparatus and media, the collection and handling of samples, and the intervals and conditions of storage allowable between collection and examination of the water sample.

broth, or formate ricinoleate broth. For the purpose of this test, all are equivalent, but it is recommended that the laboratory worker base his selection of any one of these confirmatory media upon correlation of the confirmed results thus obtained with a series of completed tests, and that he select for use the liquid confirmatory medium yielding results most nearly agreeing with the results of the completed test. The incubation period for the selected liquid confirmatory medium shall be 48 hours at 37° C. and the formation of gas in any amount during this time shall be considered to constitute a positive confirmed test.

1.8. *The standard portion of water* for the application of the bacteriological test may be either:

(a) Ten milliliters (10 ml.) or

(b) One hundred milliliters (100 ml.)

1.9. *The standard sample* for the bacteriological test shall consist of five (5) standard portions of either:

(a) Ten milliliters (10 ml.) or

(b) One hundred milliliters (100 ml.) each.

In any disinfected supply the sample must be freed of any disinfecting agent within twenty (20) minutes of the time of its collection.[2]

1.10. *The certifying authority* is the Surgeon General of the United States Public Health Service or his duly authorized and designated representatives. Reference to the certifying authority shall be applicable only in the cases of those water supplies to be certified for use on carriers subject to the Federal Quarantine Regulations. *The reporting agency* shall be understood to mean the respective official State health agencies or their designated representatives.

2. As to Source and Protection

2.1. The water supply shall be:

(a) Obtained from a source free from pollution; or

(b) Obtained from a source adequately purified by natural agencies; or

(c) Adequately protected by artificial treatment.

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[2]In freeing samples of chlorine or chloramines, the procedure given in the Standard Methods for the Examination of Water and Sewage, current edition, shall be followed.

2.2. The water supply system in all its parts should be free from sanitary defects and health hazards, and all known sanitary defects and health hazards shall be systematically removed at a rate satisfactory to the reporting agency and to the certifying authority. Approval of public water supplies by the reporting agency and the certifying authority will be conditioned by the existence of:

(a) Rules and regulations prohibiting connections or arrangements by which liquids or chemicals of unsafe, unknown, or questionable quality may be discharged or drawn into the public water supply:

(b) Provisions to enforce such rules and regulations effectively on all new installations; and

(c) A continuing program to detect health hazards and sanitary defects within the water distribution system.

2.21 *Applications.*—For the purposes of these Standards, responsibility for conditions in the water supply system shall be considered to be held by:

(a) The water purveyor from the source of supply to the connection to the customer's service piping, and

(b) The owner of the property served and the municipal, county, or other authority having legal jurisdiction from the point of connection to the customer's service piping to the free-flowing outlet of the ultimate consumer.

3. As to Bacteriological Quality

3.1. *Sampling.*—The bacteriological examination of water considered under this section shall be of samples collected at representative points throughout the distribution system.

The frequency of sampling and the location of sampling points on the distribution system should be such as to determine properly the bacteriological quality of the water supply. The frequency of sampling and the distribution of sampling points shall be regulated jointly by the reporting agency and the certifying authority after investigation by either agency, or both, of the source, method of treatment, and protection of the water concerned.

The minimum number of samples to be collected from the distribution system and examined by the reporting agency or its designated representatives each month should be in accordance with the

number as determined from the graph presented in Figure 1 of these Standards[3] which is based upon the relationship of population served and minimum number of samples per month:

Population served	Minimum number of samples per month
2,500 and under	1
10,000	7
25,000	25
100,000	100
1,000,000	300
2,000,000	390
5,000,000	500

In determining the number of samples examined monthly, the following samples may be included, provided all results are assembled and available for inspection and the laboratory methods and technical competence of the personnel are approved by the reporting and certifying agencies:

(a) Samples examined by the reporting agency.
(b) Samples examined by local health department laboratories.
(c) Samples examined by the water works authority.
(d) Samples examined by commercial laboratories.

Daily samples collected following an unsatisfactory sample as provided in sections 3.22 and 3.24 shall be considered as special samples and shall not be included in the determination of the number of samples examined monthly. Neither shall subsequent unsatisfactory samples in this daily series be used as a basis for prohibiting the supply, provided that (1) immediate and active efforts are made to locate the cause of such contamination, (2) immediate action is taken to eliminate such cause, and (3) samples taken following such remedial action are satisfactory.

The laboratories in which these examinations are made and the methods used in making them shall be subject to inspection at any time by the designated representatives of the certifying authority and reporting agency. Compliance with the specified procedures and the

[3]For the purpose of uniformity and simplicity in application, the number of samples to be examined each month for any given population served shall be determined from the graph in accordance with the following:
For populations of 25,000 and under to the nearest 1.
For populations of 25,001 to 100,000 to the nearest 5.
For populations of 100,001 to 2,000,000 to the nearest 10.
For populations of over 2,000,000 to the nearest 25.

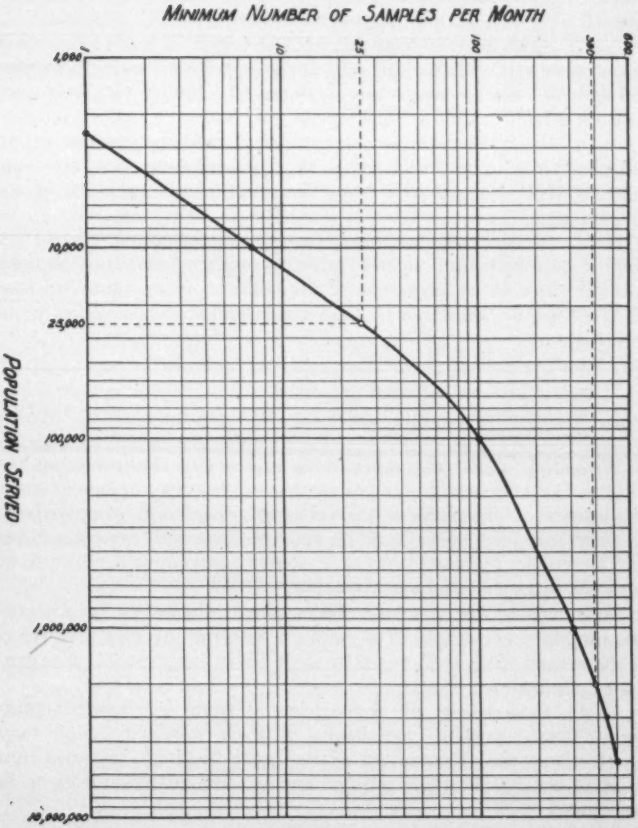

FIG. 1.—RELATION BETWEEN MINIMUM NUMBER OF SAMPLES TO BE COLLECTED PER MONTH AND POPULATION SERVED.

results obtained shall be used as a basis for certification, in accordance with the application given below:

3.2. *Application.*—Applications 3.21 and 3.22 given below shall govern when ten milliliter (10 ml.) portions are used and applications 3.23 and 3.24 shall govern when one hundred milliliter (100 ml.) portions are used.[4]

3.21. Of all the standard ten milliliter (10 ml.) portions examined per month in accordance with the specified procedure, not more than ten (10) per cent shall show the presence of organisms of the coliform group.

3.22. Occasionally three (3) or more of the five (5) equal ten milliliter (10 ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than

(a) Five (5) per cent of the standard samples when twenty (20) or more samples have been examined per month.
(b) One (1) standard sample when less than twenty (20) samples have been examined per month.

Provided further that when three or more of the five equal ten milliliter (10 ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.[5]

3.23. Of all the standard one hundred milliliter (100 ml.) portions examined per month in accordance with the specified procedure, not more than sixty (60) per cent shall show the presence of organisms of the coliform group.

3.24. Occasionally all of the five (5) equal one hundred milliliter (100 ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than

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[4]It is to be understood that in the examination of any water supply the series of samples for any one month must conform to both of the above requirements, either 3.21 and 3.22 or 3.23 and 3.24, respectively.

[5]When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 10 ml. to 0.1 ml. or less.

(a) Twenty (20) per cent of the standard samples when five (5) or more samples have been examined per month.
(b) One (1) standard sample when less than five (5) samples have been examined per month.

Provided further that when all five of the standard one hundred milliliter (100 ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.[6]

3.25. The procedure given, using a standard sample composed of five standard portions, provides for an estimation of the most probable number of coliform bacteria present in the sample as set forth in the following tabulation:

Number of portions		Most probable number of coliform bacteria per 100 ml.	
Negative	Positive	When 5-10 ml. portions are examined	When 5-100 ml. portions are examined
5	0	Less than 2.2	Less than 0.22
4	1	2.2	0.22
3	2	5.1	0.51
2	3	9.2	0.92
1	4	16.0	1.60
0	5	More than 16.0	More than 1.60

4. As to the Physical and Chemical Characteristics

4.1. *Physical characteristics.*[7]—The turbidity of the water shall not exceed 10 ppm (silica scale), nor shall the color exceed 20 (standard cobalt scale). The water shall have no objectionable taste or odor.

4.2. *Chemical characteristics.*—The water shall not contain an excessive amount of soluble mineral substance, nor excessive amounts of any chemicals employed in treatment. Under ordinary circumstances, the analytical evidence that the water satisfies the physical

[6]When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 100 ml. to 1.0 ml. or less.

[7]The requirements in Section 4.1 relating to turbidity and color shall be met by all filtered water supplies. Turbidity and color limits for unfiltered waters and the requirements of freedom from taste or odor for either filtered or unfiltered waters should be based on reasonable judgment and discretion, giving due consideration to all the local factors involved.

and chemical standards given in sections 4.1 and 4.21 and simple evidence that it is acceptable for taste and odor will be sufficient for certification with respect to physical and chemical characteristics.

4.21. The presence of lead (Pb) in excess of 0.1 ppm, of fluoride in excess of 1.5 ppm, of arsenic in excess of 0.05 ppm, of selenium in excess of 0.05 ppm, of hexavalent chromium in excess of 0.05 ppm, shall constitute grounds for rejection of the supply. These limits are given in parts per million by weight and a reference to the method of analysis recommended for each determination is given in section 4.31. Salts of barium, hexavalent chromium, heavy metal glucosides, or other substances with deleterious physiological effects shall not be added to the system for water treatment purposes.

Ordinarily analysis for these substances need be made only semi-annually. If, however, there is some presumption of unfitness because of these elements, periodic determination for the element in question should be made more frequently.

Where experience, examination, and available evidence indicate that such substances are not present or likely to be present in the water supplies involved, semi-annual examinations are not necessary, provided such omission is acceptable to the reporting agency and the certifying authority.

4.22. The following chemical substances which may be present in natural or treated waters should preferably not occur in excess of the following concentrations where other more suitable supplies are available in the judgment of the certifying authority. Recommended methods of analysis are given in section 4.3.

Copper (Cu) should not exceed 3.0 ppm.
Iron (Fe) and manganese (Mn) together should not exceed 0.3 ppm.
Magnesium (Mg) should not exceed 125 ppm.
Zinc (Zn) should not exceed 15 ppm.
Chloride (Cl) should not exceed 250 ppm.
Sulfate (SO_4) should not exceed 250 ppm.
Phenolic compounds should not exceed 0.001 ppm in terms of phenol.

Total solids should not exceed 500 ppm for a water of good chemical quality. However, if such water is not available, a total solids content of 1,000 ppm may be permitted.

For chemically treated waters, *i.e.*, lime softened, zeolite or other ion-exchange treated waters, or any other chemical treatments, the following three requirements should be met:

(1) The phenolphthalein alkalinity (calculated as $CaCO_3$) should not be greater than 15 ppm plus 0.4 times the total alkalinity. This requirement limits the permissible pH to about 10.6 at 25° C.

(2) The normal carbonate alkalinity should not exceed 120 ppm. Since the normal alkalinity is a function of the hydrogen-ion concentration and the total alkalinity, this requirement may be met by keeping the total alkalinity within the limits suggested below when the pH of the water is within the range given. These values apply to water at 25° C.

pH range	Limit for total alkalinity (ppm as $CaCO_3$)
8.0 to 9.6	400
9.7	340
9.8	300
9.9	260
10.0	230
10.1	210
10.2	190
10.3	180
10.4	170
10.5 to 10.6	160

(3) If excess alkalinity is produced by chemical treatment, the total alkalinity should not exceed the hardness by more than 35 ppm (calculated as $CaCO_3$).

4.3. Recommended methods of analysis:[8]

4.31. Ions with required limits of concentration.

Arsenic (As): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, p. 390; also "Colorimetric Microdetermination of Arsenic," Morris B. Jacobs and Jack Nagler, Industrial and Engineering Chemistry, Anal. Ed., *14:* 442 (1942).

Fluoride (F): Standard Methods for the Examination of Water and Sewage, current edition; also Methods of Determining Fluorides, Committee Report, A. P. Black, Chairman, Journal American Water Works Association, *33:* 1965-2017 (1941).

Lead (Pb): Standard Methods for the Examination of Water and Sewage, current edition.

Selenium (Se): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, pp. 11 and 417; also Robinson, W. O., Dudley, H. C., Williams, K. T., and Byers, H. G., "The Determina-

[8]For the chemical determinations referred to in this report, when given, the methods of analysis recommended by the Association of Official Agricultural Chemists are satisfactory and may be substituted for those recommended in the Standard Methods for the Examination of Water and Sewage, current edition, which are specifically cited.

tion of Selenium and Arsenic by Distillation." Industrial and Engineering Chemistry, Anal. Ed., *6:* 274 (1934).

Hexavalent Chromium: Standard Methods for the Examination of Water and Sewage, current edition.

4.32. Ions and substances with suggested limits of concentration

Copper (Cu): Standard Methods for the Examination of Water and Sewage, current edition.

Iron (Fe) and *Manganese* (Mn): Ibid.

Magnesium (Mg): Ibid.

Zinc (Zn): Ibid.

Chloride (Cl): Ibid.

Sulfate (SO_4): Ibid.

Phenolic compounds: Ibid.

Total solids: Ibid.

Alkalinity: Ibid.

PROCEEDINGS

November 1945 Meeting

Hotel Statler, Boston, Mass.

Thursday, November 15, 1945

President Harold W. Griswold in the Chair.

The President reported the death of Frank J. Gifford, former Secretary of the Association, which occurred shortly after Mr. Gifford had been elected Secretary Emeritus. Past President Karl R. Kennison read a memoir of Mr. Gifford, which is printed elsewhere in this issue of the JOURNAL.

President Griswold announced the election as Secretary of Walter C. Conroy, General Superintendent of the Belmont Water Department.

Secretary Conroy announced the election of the following new members:

Walter M. Campbell, Superintendent, Water Division, P.W.D., Boston, Mass., and Sherman L. Rogers, Assistant Superintendent, Distribution Division, Metropolitan District Water Bureau, Hartford, Conn.

The Secretary reported the death on October 21, 1945, of Arthur V. Ruggles, member.

A talk on "Experiences of a Transportation Officer in the ETO" was given by Lt. Col. Richard Kimball, formerly Deputy Section Transportation Officer, Oise Intermediate Section; Building News Service, Boston, Mass.

A paper "Internal Combustion Engines in Water Works and Sewage Plants" was read by A. M. Boehm, Worthington Pump and Machinery Corp., New York, N. Y.

Moving picture films were shown by Lt. Col. Albert A. Ross, C.E., Office of Post Engineer, Camp Myles Standish, Mass. The first part of his program consisted of a short reel on the 1933 convention at Fitchburg. The remaining reels were U. S. Army films.

December 1945 Meeting

Hotel Statler, Boston, Mass.

Thursday, December 20, 1945

President Harold W. Griswold in the Chair.

Secretary Conroy announced the election of the following new members:

Clyde B. Rowntree, Textile Bacteriologist, Laconia, N. H.; Jerome L. Spurr, Assistant Civil Engineer, Metropolitan District Water Supply Commission, Lt. Col., U. S. Army Engineers (on leave), Wellesley, Mass.; Alfred A. Osterman, Inspector, Water Division, P.W.D., Boston, Mass.; Clifford E. Hodgman, Superintendent, Lynnfield Center Water Supply, Lynnfield, Mass.; G. Arthur Faneuf, Assistant Superintendent, Water Works, Concord, N. H.; E. Shaw Cole, Chief Engineer, The Pitometer Co., New York, N. Y.; Philip E. Bond, Member of Firm of Tighe & Bond, Consulting Engineers, Holyoke, Mass. (Reinstatement).

President Griswold announced that there are available some surplus copies of the Journal that go back for some years and that, if any members of the Association wish, they can obtain them at a nominal price through the Association office.

A paper "Prediction of Frost Penetration" was read by William L. Shannon, U. S. Engineer Office, Boston, Mass.

A talk on "Infectious Hepatitis" was given by Dr. Roy F. Feemster, Director, Division of Communicable Diseases, Massachusetts Department of Public Health.

January 1946 Meeting

Hotel Statler, Boston, Mass.

Thursday, January 10, 1946

President Harold W. Griswold in the Chair.

Secretary Conroy announced the election to membership of Ernest G. Fenn, Jr., representing the Fairfield State Hospital, Newtown, Conn.

The Secretary reported the death on November 9, 1945, of John J. Moore, who had been a member since 1910.

A paper "Sanitary Public Health in Experiences in Europe" was read by Leonard W. Trager, Director of Sanitary Engineering, State Board of Health, Concord, N. H.

A paper "Water Supplies in the Asiatic-Pacific Area" was read by Lt. Edwin B. Cobb, Civil Engineer Corps, USNR, with Metcalf & Eddy, Boston, Mass.

Superintendents' Round Table

December 20, 1945

The topic "Meter Maintenance and Practices" was presented to the Superintendents' Round Table by Dean E. Hawkins, Assistant Superintendent, Water Department, Keene, N. H. Limited discussion was made by those present concerning methods of repairing frozen house meters and charging for same, individual meter installations versus series or battery units, testing of meters, standardization of makes and settings, and methods of meter reading. A severe snow storm prevented many superintendents from reaching the meeting, with the result that attendance was small.

Discussion was confined in general to procedure adopted at Keene, N. H., Portland, Me., and Danvers, Mass.

Superintendents' Round Table

January 10, 1946

"Plant Maintenance and Care of Equipment" was the subject for consideration at this meeting and discussion was led by Chairman Roger G. Oakman of Needham, Mass. In his town preventive maintenance includes repacking and cleaning pumps every six months, checking motors at frequent intervals, inspecting Diesel engines twice a week and overhauling them twice a year. Chlorinators and all other water-department equipment are also inspected and overhauled periodically.

Superintendents from other towns commented on maintenance methods used in their departments. Particular emphasis was placed upon the importance of keeping electric motors free of dust and dirt and upon proper inspection of Diesel-engine operation. Results obtained from "break-down insurance" were related by several of those present and discussion of the merits of such insurance concluded the meeting.

Chemists' Round Table

December 20, 1945

The topic "Correction of Corrosion" was presented to the Chemists' Round Table by Joseph A. McCarthy, Chief of Laboratory, Lawrence Experiment Station, Massachusetts Department of Public Health.

Mr. McCarthy discussed the data developed at a symposium on "Corrosion" at a meeting of the American Chemical Society and published in the September and October issues of "Industrial and Engineering Chemistry". He discussed the seven causes of failure of calcium carbonate precipitation mentioned by Powell. He cited two experiences with corrosion corrective treatment. In the first instance, at a State institution using a ground water where soda ash was used, results were quite satisfactory with a marked decrease in the iron content of tap samples and a slight drop in the hardness of the water. The other instance was a municipal surface supply having an alkalinity of 15 ppm and a calcium content of 5 ppm. The use of soda ash to raise the pH to 8.7 resulted in some improvement in the water. In one section of main where considerable growth of slime had taken place, an unpleasant taste developed in the water due to permeation of the slime by the caustic. Considerable flushing of a 10-in. section of main with few takers resulted in an increase in the value of "C" from 42 to about 100. Another section of main continued to give high iron results. To correct this, the pH of the water was raised to 9.6 and the main was bled at the rate of 1,000 gal an hour. This was carried out only during week-ends and gave a satisfactory water for several weeks but, when bleeding was stopped, high iron content again resulted.

During the discussion, experiences with the use of hexametaphosphate were cited and in one instance, where experiences with its use over a period of 4 years were given, it was shown that, while the iron content at dead ends decreased quite rapidly with its use, there was one dead end where the iron content was up to 0.45 ppm at the end of one year. At the end of the second year it was down to practically zero and it has remained that way since. The pH of this water is 5.8. Experiments with nickel-plated steel pipe were cited and, while the results were favorable, the pipe appeared to be quite expensive.

The effects of the use of other phosphate corrective agents were discussed and an instance was cited where the use of these agents caused a marked increase in the algal growth in treated water in open reservoirs.

LAZARUS RUBIN

CHEMISTS' ROUND TABLE

January 10, 1946

The topic "War Time Water Problems" was presented to the Chemists' Round Table by Leonard W. Trager, Director, Division of Sanitary Engineering, New Hampshire Department of Health. Mr. Trager began his talk with some vivid and humorous word pictures of conditions in the war areas familiar to him as a public health officer and also explained his military officer's status in the U. S. Army.

The first topic he discussed was the inefficiency of the bacteriological laboratories in Sicily, Italy and Sardinia. Not only as a result of war but because transportation from the provincial capitals to the towns and villages was never adequate, a regular water sampling procedure could not be undertaken by the provincial laboratories. This fact, combined with what might be considered by us in this country as a lack of proper understanding of the value of having a regular water sampling procedure, resulted in very little analytical work being done. These things were emphasized by the speaker, because at the time of his inspections he did not find a laboratory that had even a single sample under examination, so all his data re-

garding procedures, materials used, etc., had to be collected by word of mouth. Some of the data are given below.

Coliform examinations are made but do not conform to the procedures outlined by the Standard Methods of the American Public Health Association. A so-called Neri solution is used instead of lactose broth at a large number of laboratories. Following this a multitude of procedures and materials is used. No pretense is made at standardization.

As in the above, the amount of water placed in the broth tubes varied with the laboratories. In one place 30- and 40-ml tubes were used. No 1-ml tubes were ever analyzed and only rarely were 10-ml. At another laboratory the procedure called for ten 10-ml tubes, five 50-ml tubes and two 100-ml tubes. In this laboratory there were only 15 sample bottles. In addition, the laboratory was completely out of illuminating gas and very short of alcohol, petroleum and peptone. In still another place the procedure followed for the inoculation of fermentation tubes was to place 300 cc of water in an Erlenmeyer flask, followed by 18 cc of the so-called Neri solution number one, then 9 cc of Neri solution number two, then 3 cc of Bacterio Statico and finally 3 cc of fuchsin. This mixture of broth media and water was then measured out and placed in gas tubes. Finally, at still another laboratory there were only about 20 ten-cc fermentation tubes, which fact limited the laboratory's water analysis capacity to two samples at one time.

Contrasting the sources of water supply, Mr. Trager told of taking water from galleries which were shut off during the night to save waste. Such a condition proved to be unsound practice, for by allowing a continuous flow the bacteriological conditions were greatly improved. Few of the domestic water supplies were filtered. In one instance a reservoir with a capacity of 125 mil gal was less than one-half full—60 mil gal. In another case a 0.5-mgd supply had to take care of 55,000 soldiers and the civilian population. This allowed 10 gal daily per capita, on the average.

All chemical treatment had to be estimated and the dosage worked out by the general rule of trial and error. On the average the alum dosage equaled 1 grain per gallon. The pH in one supply before treatment was guessed at—about 8.8 before and 5.0 after treatment.

From the coagulation basins, the water entered six roughing filters in series and then filtered through fine sand or slow sand filters. The final effluent was chlorinated by means of siphoning a solution of old chlorite of lime—approximately 25% available—to effect approximately 1 ppm of chlorine. Again Mr. Trager emphasized that everything was indefinite.

Mosquito control offered Mr. Trager a problem in substitution. When the chemical, Paris green, was scarce or unavailable, he had to substitute Diesel oil. The civilians stole the oil, thereby defeating its purpose as a mosquito exterminator.

To show how one budget was drawn up and presented for approval, Mr. Trager said that it contained, among other things, the following items:

1. Transportation of workers to mixing stations.
2. Transportation of workers' families.
3. Extra compensation for good work.
4. Fund for Malaria Committee extra in war zone.
5. Raise for committee approved by A.M.G. (no approval ever given by Military Government).
6. Expense for committee.
7. Fund for director (two items).
8. Fund for secretary of committee.
9. Propaganda expenses.
10. Premium for encouragement.

The total to be paid by the communes was to be about 1/16 the amount estimated to be paid by A.M.G. This estimate was submitted by the Italians and disapproved by the Army. Consequently the Italians paid the bill.

An interesting installation wherein an aqueduct ran for great distances, either in pipes or open channels, from the lower third of the boot-shape peninsula to the extremities of the heel formation of Italy, covering enormous areas, was clearly explained by Mr. Trager.

Mr. Trager reported on various diseases in France, such as typhoid fever, undulant fever, dysentery, etc., and cited situations that might be considered as epidemic in America, that held no immediate concern for the French health officials. Again Mr. Trager submitted interesting data. For the seven southeastern departments of France, which include the Riviera, 133 cases of typhoid fever were

reported for the month of July, 1945. Toulon, which is not a large city (about 30,000), had 31 cases in this period. During this same period, 99 cases of diphtheria were reported in these departments.

In closing, Mr. Trager briefly told of the shellfish tolerance by public health officials of France. During a food shortage, contaminated or known polluted shellfish were disregarded and the people allowed to sell this foodstuff, regardless of the consequences.

The next speaker was William R. Clary, District Engineer, Massachusetts Department of Public Health. Mr. Clary corrected the title of his talk by explaining that it should have been "What Happens to a Sanitary Engineer upon Enlistment". He reported for duty and found himself in a doctors' detail. In the order of military training, he was taught the ground work in military affairs, the elements of water sanitation and military etiquette. After traveling throughout the country upon various duties, such as studying water supplies and distribution, softening problems and reduction of iron content, he was confronted with the ever-present problem of chlorination. According to Mr. Clary, military regulations required specific standards, which at times were difficult to satisfy, and he offered examples of the necessity of meeting these regulations and abiding by them.

To exemplify the diversity of a sanitary officer's detail in the Army, Mr. Clary told of such duties as guarding industries from damage or sabotage, teaching men the significance of water sanitation, and correcting controversies between States' rights and military privileges.

Mr. Clary's overseas duty in the Philippines was uneventful. With the war over, he became eligible for release, returned to the United States and entered civilian sanitary status again.

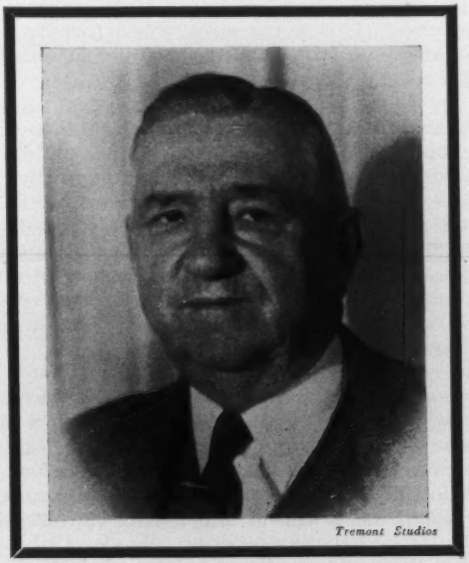
Lt. Edwin B. Cobb, CEC, USNR, accepted an invitation to make a few remarks and spoke briefly on the Navy's shortcomings. The Navy has two classifications for water treatment: the shore and ship details. According to Lt. Cobb, the shore unit lacks engineers, especially civil engineers for shore installations. He recommended older engineers for this work. The Navy, too, had its difficulties in chlorination in the Pacific theater, for, strangely enough, Lt. Cobb advocated chlorination of distilled water with a residual of 1 ppm lasting 20 minutes. This condition exists only when the source of water is highly polluted, as from the Yangtze river.

JOSEPH C. DERBY

MEMOIR OF FRANK J. GIFFORD

[Read November 15, 1945.]

The New England Water Works Association has lost an able and faithful worker by the sudden death of Frank J. Gifford, Secretary of the Association, at his home in Plaistow, N. H., on October 5, 1945.



FRANK J. GIFFORD
1878-1945

Frank Gifford served the New England Water Works Association loyally and well as its secretary for over a quarter of a century. His untiring efforts on behalf of the Association and his strong stand

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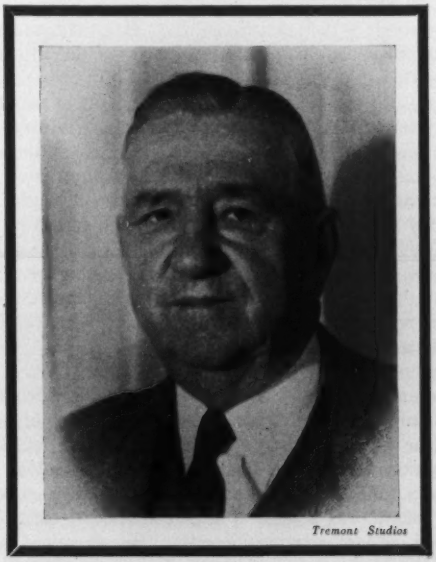

FRANK J. GIFFORD
1878-1945

Frank Gifford served the New England Water Works Association loyally and well as its secretary for over a quarter of a century. His untiring efforts on behalf of the Association and his strong stand

for the proper conduct of its affairs were of great value in building up and maintaining the Association in its position of leadership.

He was born in Fall River, Mass., February 24, 1878. His ancestors came from England in early Colonial days, settling first in Jamestown, Va., and later in Westport, Mass. After graduating from the Fall River High School in 1896, he went to work for the Fall River Water Department, rising to the position of Assistant Superintendent. In 1915, he left Fall River to become Superintendent, later Manager, of the Dedham (Mass.) Water Company. He retired from this position in 1936 to engage in private practice as a public-utility consultant and to manage certain business interests with which he was connected.

In his mature years, he took up the study of law, specializing in public-utility law, and graduated from Suffolk Law School in 1930.

During most of his life, he was active in the water-works field and, even after his retirement from the Dedham Water Company, continued to maintain his interest in water-works activities. In 1920, he was elected Secretary of the New England Water Works Association. Due to ill health, he had tendered his resignation only the day before he died, to take effect upon the appointment of a successor; and on that day, the Executive Committee of the Association, in accepting his resignation, elected him Secretary Emeritus in recognition of his long and valued services.

After he retired as Manager of the Dedham Water Company, he purchased an attractive home in Plaistow, N. H., which he modernized. He busied himself with gardening and the raising of small fruits. A year ago he was elected to the New Hampshire legislature but, due to his serious illness, was unable to attend a session. He had a keen interest in golf and played an above-the-average game.

Frank Gifford was a man of firm convictions, outspoken, loyal to his friends, and of sterling integrity. His devotion to the New England Water Works Association was deep and abiding.

In 1906, he married Gertrude Piercy of Fall River, who survives him. He is survived also by one son, Allan T. Gifford, who is Assistant Professor of Hydraulic Engineering at Massachusetts Institute of Technology, and by three grandchildren and a brother, Adam W. Gifford.

HORACE L. CLARK
KARL R. KENNISON

WALTER C. CONROY ELECTED SECRETARY

To succeed the late Frank J. Gifford, the Executive Committee on November 1, 1945, elected Walter C. Conroy Secretary of the New England Water Works Association. Mr. Conroy has been a member of the Association since 1929 and has served on various committees.

Kaiden-Keystone

WALTER C. CONROY

For the past 18 years he has been associated with the Water Department of Belmont, Mass. From 1928 to 1935 he was a member of the Board of Water Commissioners, serving as Chairman of the Board in 1932-33. Mr. Conroy was Office Manager of the Water Department from 1936 to 1941 and for the past five years he has been General Superintendent.

BOOKLET ENTITLED "1945 CONVENTION"

The Water and Sewage Works Manufacturers Association has recently published a booklet entitled "1945 Convention." This publication was prompted by patriotic motives, as stated on one of its first pages: "Like all patriotic Americans, we are cooperating with Uncle Sam and are not going to overburden an overloaded transportation system by holding our usual conventions and exhibits." Therefore the booklet was prepared, depicting the exhibits of the various concerns which normally would have been seen at a convention of the New England Water Works Association in the fall of 1945.

The booklet represents much effort and is exceedingly well executed. It will prove of interest to everyone in the water works industry. The New England Water Works Association commends this publication in the highest terms. Anyone who has not received a copy may obtain one by writing to Arthur T. Clark, Secretary-Manager, Water and Sewage Works Manufacturers Association, 170 Broadway, New York 7, N. Y.

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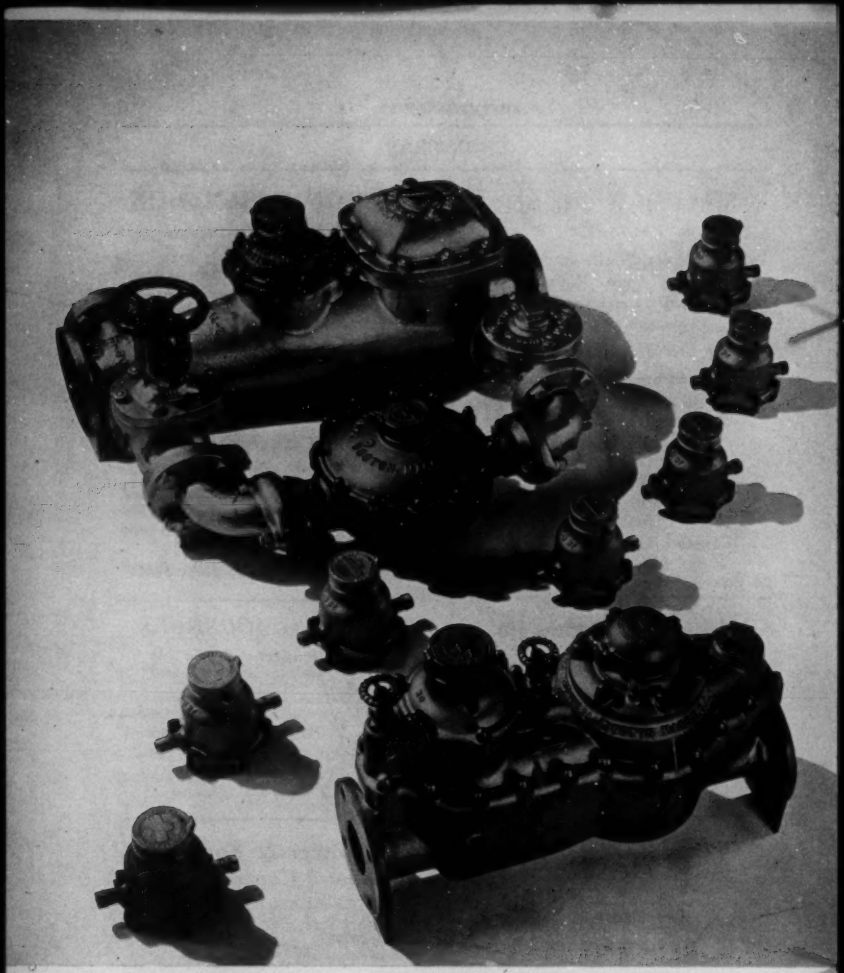

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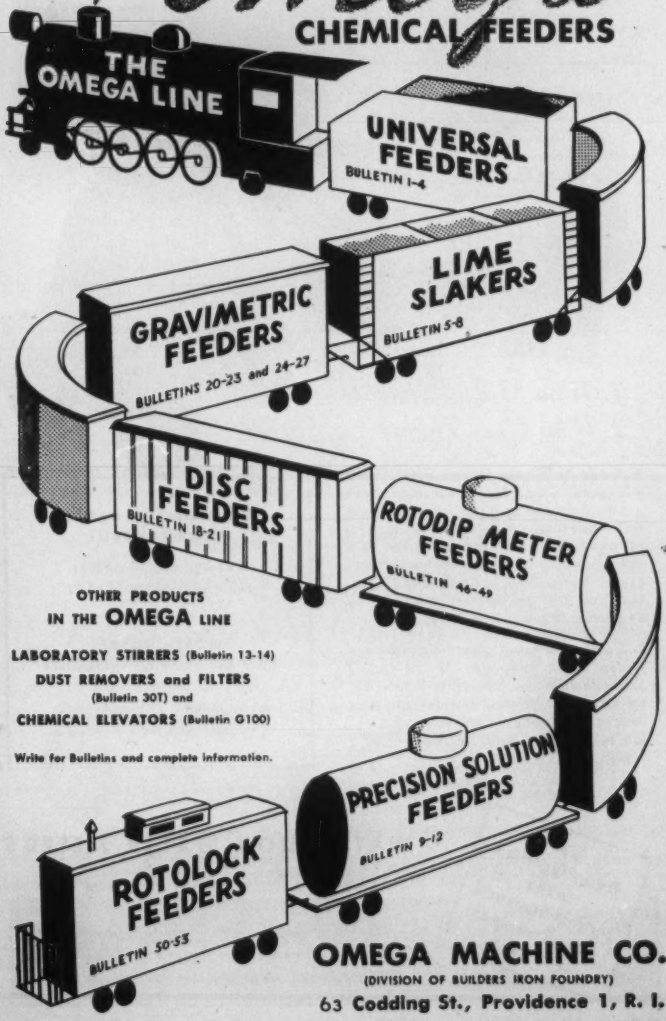

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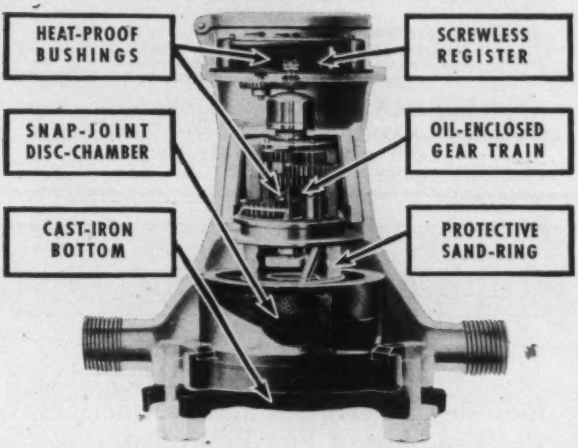

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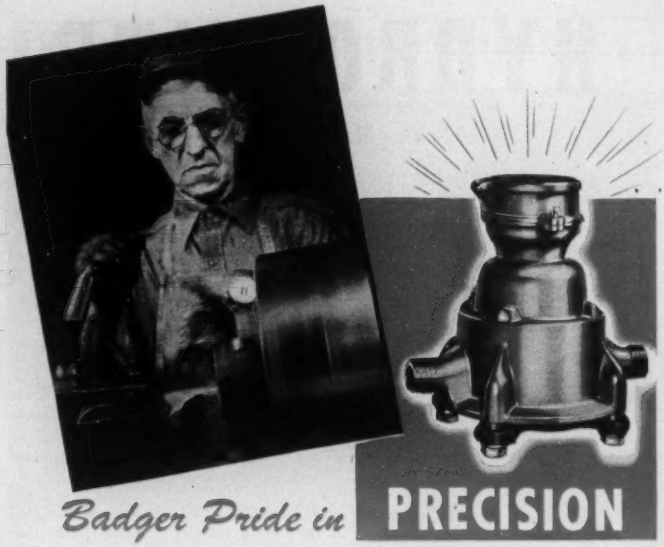

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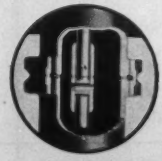

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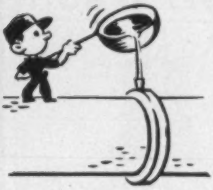

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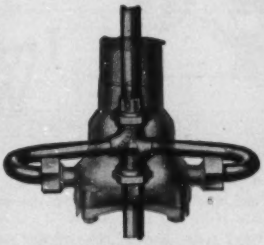

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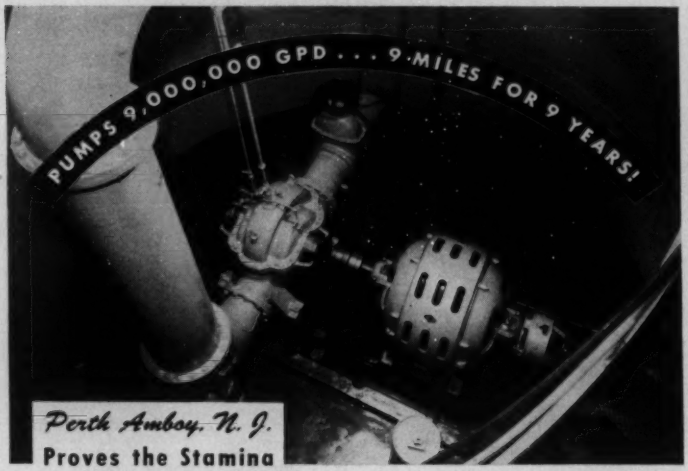

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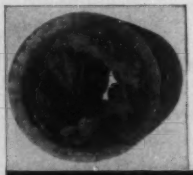

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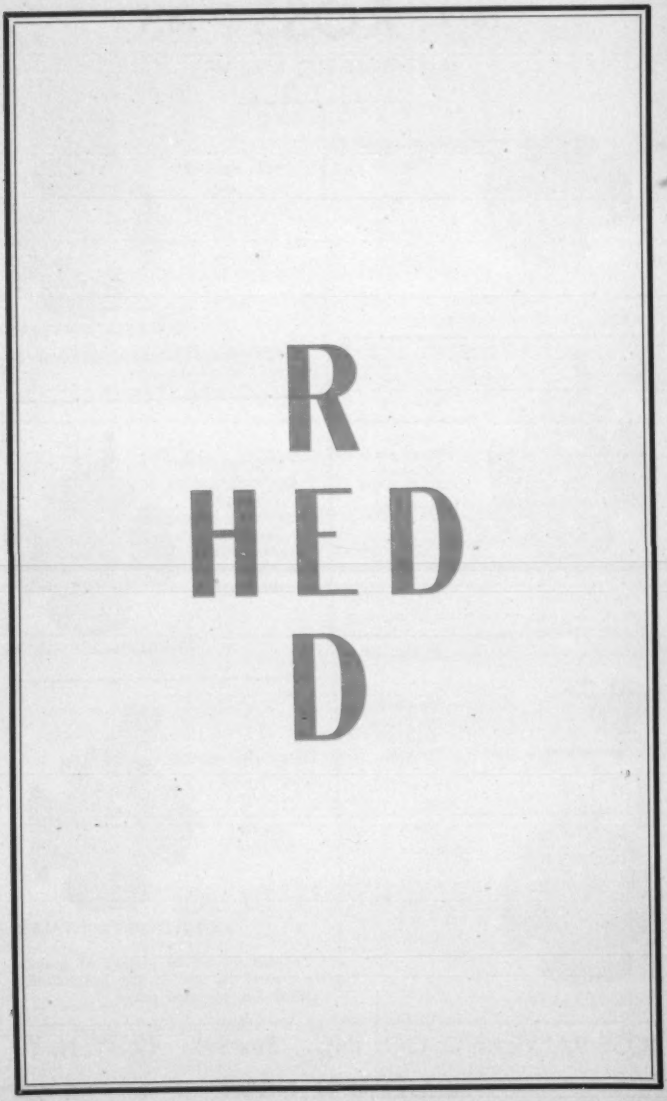
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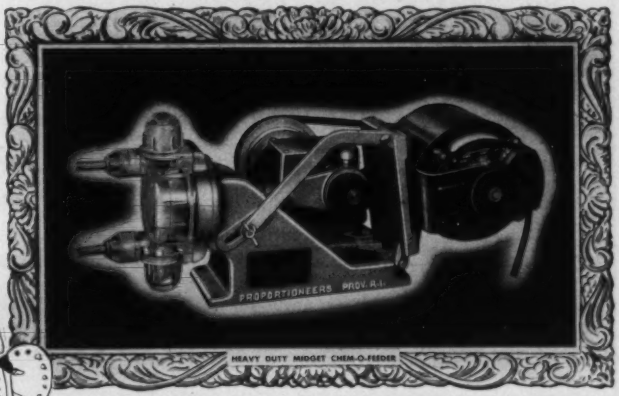

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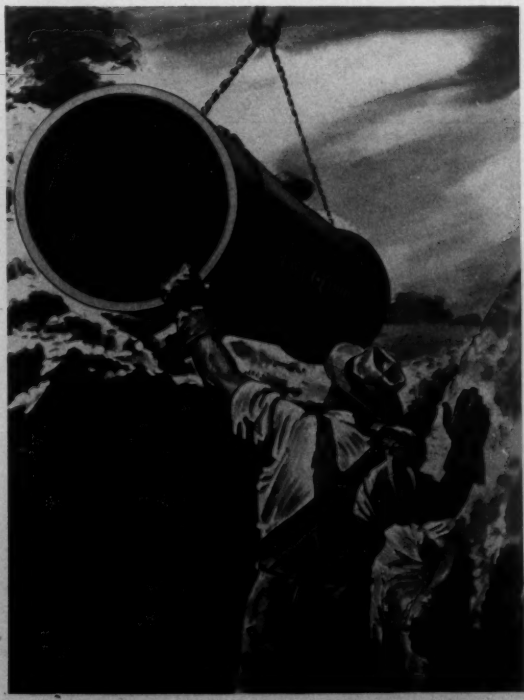

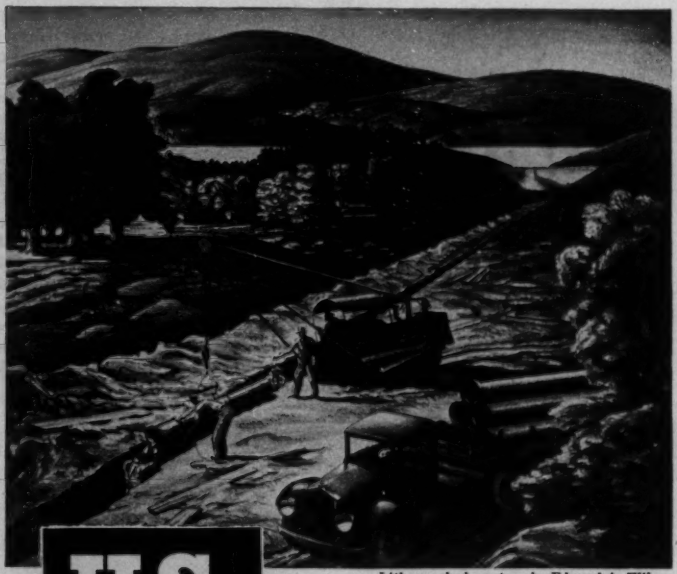

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